LATIS Lot 1: Strathclyde Regional Transport Model Development
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DEMAND MODEL DEVELOPMENT

LATIS LOT 1: STRATHCLYDE REGIONAL TRANSPORT MODEL DEVELOPMENT

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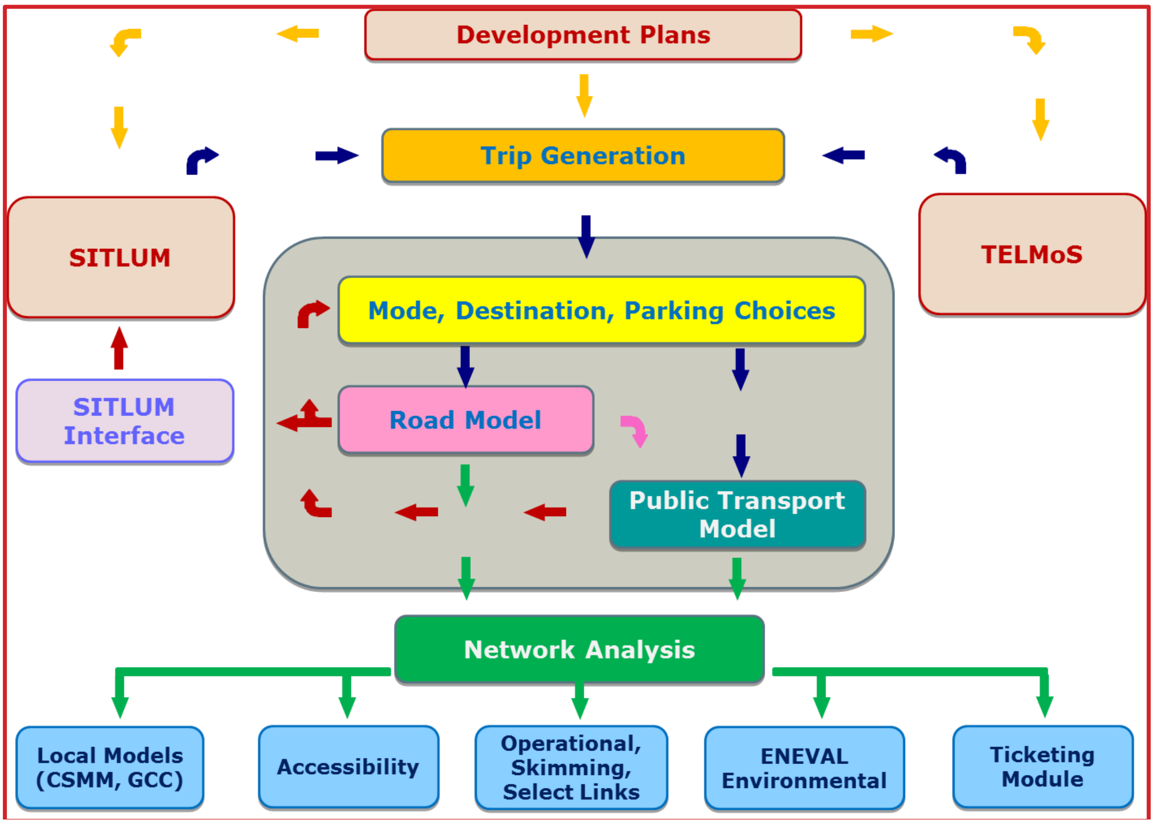
1. OVERVIEW

1.1 Overview

1.1.1 A new regional transport model of Strathclyde (SRTM) is being developed 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 model structure is illustrated below in Figure 1.

Figure 1. **SRTM Model Structure**



1.1.3 The approach provides the traditional 4-stage multi-modal modelling functionality, across the Strathclyde area, including trip generation (with links to TELMoS and SITLUM), behavioural models covering mode, destination and parking, and road and public transport assignment models for detailed route choice.

1.1.4 This note documents the demand model module of the above structure.

1.2 Terminology

1.2.1 Before discussing the actual components of the model, it is beneficial to lay out definitions for each of the commonly used terms to avoid ambiguity.

Zone Systems

1.2.2 The trip end model is required to provide outputs in a zone system consistent with the SRTM demand model which consists of 1299 zones covering the Strathclyde area.

1.2.3 These zones are structured as follows:

- Zones 1 to 1233 – zones with planning data sourced from TELMoS;
- Zones 1234 to 1247 – Park and Ride point zones;
- Zones 1248 to 1253 – 6 spare zones for Airports and key ports; and
- Zones 1254 to 1299 – External zones linked to TMfS outputs.

1.2.4 The planning data inputs which trip ends are derived from are supplied from TELMoS which uses a larger zone system consistent with TMfS:14 and an example overlay of the two zone systems is shown below.

1.2.5 The zone system is discussed in more detail in Appendix A, though it should be noted that this was prior to the final revisions to the zone system. These revisions placed the Isle or Arran as an external zone, and reduced the number of park and ride point zones to enable a considerable improvement in model run times.

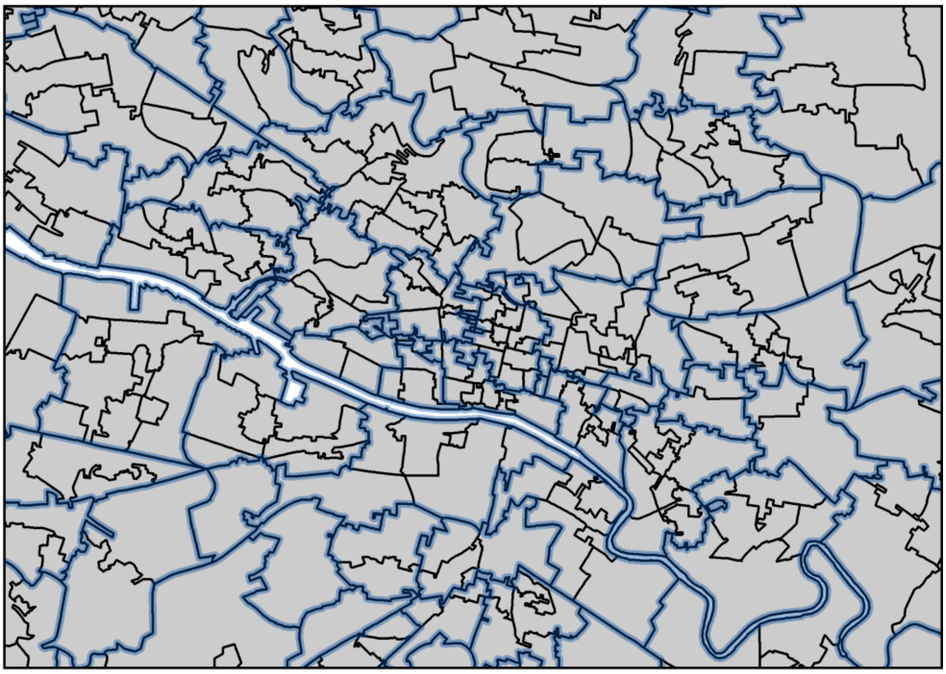


Figure 2. **Zone System Overlay Example: TELMoS zones in blue outline; SRTM zones in black**

Time Periods

1.2.6 The SRTM demand model requires 24 hour trip ends which are used to define travel for five different time periods within the SRTM demand model:

- AM (07:00 – 10:00);
- Lunchtime (LT, 10:00 – 13:00);
- School Run (SR, 13:00 – 16:00);
- PM (16:00 – 19:00); and
- Off-peak (OP, 19:00– 07:00).

Modes

1.2.7 The SRTM demand model contains a mode choice which considers five distinct modes:

- Car;
- PT;
- Park and Ride;
- Walk; and
- Cycle.

Tours and Trip Types

1.2.8 Fundamental to the derivation of trip ends in this model is an understanding of how tours are modelled, with a tour considered as any set of trips which begin at home and end at home. Two specific types of tour will be considered:

- A simple tour which goes straight from home to a single destination and then returns directly home; and
- A non-simple tour which has an initial outbound trip from home to a first destination, an unspecified number of non-home-based trips to alternative destinations, and a final return home trip.

1.2.9 These trips are illustrated graphically below, although it is highlighted that only a single representative non-home-based trip is included here while in practice there can be multiple.

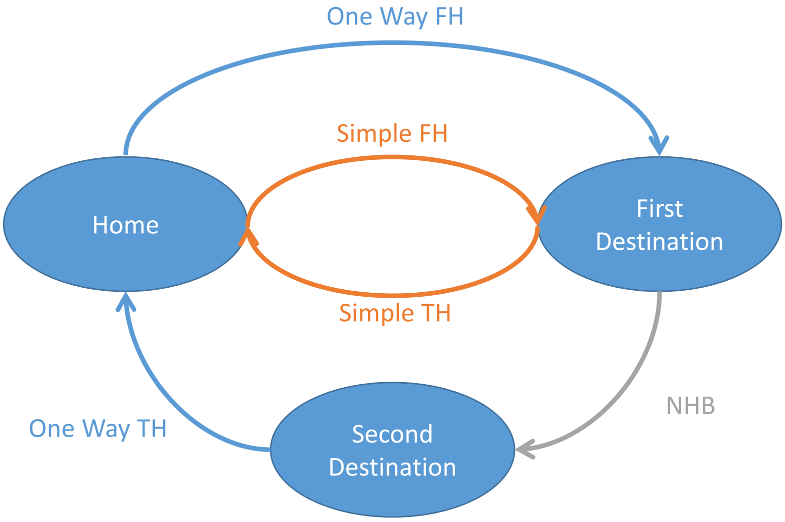


Figure 3. **Tours and Trip Types**

Demand Segments

1.2.10 The SRTM demand model disaggregates total travel into particular traveller types in order to more robustly model the choices they make, and the trip end model is the first stage of defining the different types of traveller.

1.2.11 Five travel purposes are considered:

- Home-based employer's business (EMP);
- Home-based commuters (COM);
- Home-based education (EDU);
- Home-based other (OTH); and
- Non-home-based other (NHBO).

1.2.12 Other here is considered a catch-all for any purposes which do not specifically fall into the other three categories, and notably contains escort to education, meaning that education trips solely consider those made by the person travelling to education establishments to be educated.

1.2.13 The education demand segment is in the model, and operates in the same manner as other demand segments. Education was included to improve the model's functionality, though during model development further investigation identified that the SHS based-data that would be required for the demand model side was not going to be available for the study. The user class was retained as the scripts had already been coded. The model was developed including the education user class. The expectation was that there would be good quality data available from the SHS. This turned out not to be the case.

1.2.14 The education demand segment of the demand model was already scripted and rather than remove the education demand segment and rewrite the remainder of the model due to the removed cost / demand files, the decision was taken to use lower quality data as reported through the demand model report.

1.2.15 Retired was a consequence of separating the PT matrices for concessionary travel, it made sense to carry through the age definition of concessionary / retired through the demand model and consequently through the assignment model.

1.2.16 As well as travel purposes, two different economic statuses are accounted for, retired and non-retired, as defined by both survey data and planning data i.e. there is no requirement to assume retired based on any specific age band for instance.

1.2.17 Household car availability is used to distinguish traveller types, as it has a large impact on mode choice, and this is derived based on assumptions relating to car competition (see SHS data processing note).

1.2.18 Table 1 below describes how each different purpose, socio-economic status, car availability segment, trip type and user class are combined to create demand segments.

Table 1. Demand Segment Correspondence

REF	PURPOSE	RETIRED STATUS	CAR AVAILABILITY	TRIP TYPE	USERCLASS
1	EMP	Non-Retired	All	Simple From Home	EMP
2	COM	Non-Retired	Car available	Simple From Home	COM
3	COM	Non-Retired	No car available	Simple From Home	COM
4	OTH	Non-Retired	Car available	Simple From Home	OTH
5	OTH	Non-Retired	No car available	Simple From Home	OTH
6	EDU	Non-Retired	Car available	Simple From Home	EDU
7	EDU	Non-Retired	No car available	Simple From Home	EDU
8	ALL	Retired	Car available	Simple From Home	RET
9	ALL	Retired	No car available	Simple From Home	RET
10	EMP	All	All	Non-home-based	EMP
11	Not EMP	All	Car available	Non-home-based	OTH
12	Not EMP	Non-Retired	No car available	Non-home-based	OTH
13	EMP	Non-Retired	All	One-way home-based	EMP
14	COM	Non-Retired	Car available	One-way home-based	COM
15	COM	Non-Retired	No car available	One-way home-based	COM

REF	PURPOSE	RETIRED STATUS	CAR AVAILABILITY	TRIP TYPE	USERCLASS
16	OTH	Non-Retired	Car available	One-way home-based	OTH
17	OTH	Non-Retired	No car available	One-way home-based	OTH
18	EDU	Non-Retired	Car available	One-way home-based	EDU
19	EDU	Non-Retired	No car available	One-way home-based	EDU
20	ALL	Retired	Car available	One-way home-based	RET
21	ALL	Retired	No car available	One-way home-based	RET

1.3 External Trips

1.3.1 The external road and public transport trips i.e. external-external, internal-external and external-internal are derived from the Transport Model for Scotland (TMfS14). These trips are outside and are not manipulated by the demand model.

1.3.1 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)

1.3.2 These purposes have been disaggregated based on factors obtained from the Scottish Household Survey into Other, Education & Retired, as shown in the Table 2 below.

Table 2. TMfS Purpose Disaggregation

	Road			Public Transport		
	Other	Education	Retired	Other	Education	Retired
AM	0.72	0	0.28	0.75	0	0.25
IP	0.635	0	0.365	0.58	0	0.42
PM	0.75	0	0.25	0.76	0	0.24

1.4 General Structure

1.4.1 The following chapter discusses the data processing undertaken to provide factors and calibration data for the demand model.

1.4.2 The demand model contains the following elements:

- Initial Simple Tour Mode and Destination Choice;
- One Way Trip Mode and Destination Choice;
- Free Workplace Parking Model;
- Parking Capacity Model;
- Park and Ride Model;
- Tour Aggregation;
- Assignment Preparation; and
- Model Convergence.

1.4.3 The simple tour and one-way mode and destination choice stages are discussed in the Chapter 3. The Parking models are documented within Chapters 4 and 5. Chapter 6 discusses the Park and Ride model.

1.4.4 Chapter 7 outlines the tour aggregation re-ordering stage and Chapter 8 documenting the assignment preparation stage where the matrices are converted into the formats and units required for the assignment models.

1.4.5 Chapter 9 discusses the calculation of the generalised cost matrices for subsequent loops, with Chapter 10 reporting the convergence calculation methodology.

1.4.6 Chapter 11 forms the documentation of the calibration of the final demand model.

1.4.7 Finally, Chapter 12 provides a summary of the model and recommendations for its use.

2. DEMAND MODEL DATA PROCESSING

2.1 Overview

2.1.1 A range of data sources have been used in the development of the demand model. These are:

- Scottish Household Statistics data;
- Census Journey to Work data;
- Transport Model for Scotland factors;
- Road Traffic Counts;
- PDFH data; and
- Mobile Phone Data.

2.1.2 Table 3 below shows an overview of the outputs that would be obtained from the above data sources. The last column identifies the section of this chapter that the analysis is reported within.

Table 3. Outputs from SHS Data

SOURCE	USE OF DATA	SECTION
Household Survey Database	Tour Proportions	
	Mode Shares	
	Car Occupancy Car Driver factors	
	Trip Length / Cost Distributions	
Census Journey to Work	Travel pattern analysis (Commute)	
Transport Model for Scotland factors		
Road Traffic Counts		ROAD REPORT
Passenger Demand Forecasting Handbook (PDFH)	Public Transport User Class to Ticket Class factors	PT REPORT
Mobile Phone Data (MPD)	Sector to Sector validation movements	MPD REPORT

2.2 SHS Data Processing

2.2.1 The SHS Random Adult travel diary dataset received includes all journeys which started or ended within the SPT area in the 2012-2014 SHS dataset.

2.2.2 The SHS Travel diary data records trips as a sequence of trips/journeys disaggregated into legs/stages where either the mode or journey purpose (or both) change. For the purposes of the SRTM, these trips and sub-trips are further classified by 'Trip Type', based on whether they are 'From Home', 'To Home' or 'Non-home-based', as described in the following section.

2.2.3 The first step of SHS data processing was to append flags to the data, these flags identifies the SRTM definitions of trip type, mode and journey purpose to the data. The following description and tables provide lookup tables for translating SHS data to SRTM definitions.

2.2.4 The stages can be categorised as five different trip types. These are calculated based on the stage start and stage end SHS variable. The identifier conveys if the stage at the start or end is a home trip or elsewhere. By using this it is possible to categorise the stages into the different trip types.

2.2.5 The five trip types are (as displayed earlier in Figure 3):

- Trip Type 1 (Simple From Home);
- Trip Type 2 (Simple To Home);
- Trip Type 3 (Non Simple From Home);
- Trip Type 4 (Non Simple To Home); and
- Trip Type 5 (Non Home Based).

2.2.6 For the trip type identification, the key variables are the stage unique id and the 'Home' variable from the above stage description. The process is described below.

1. If stage start is home and the immediate following stage end (with the same unique stage ID) is also home then it is classified as a trip type 1.
2. Similarly, if the stage end is home and the preceding stage start is home then it classified as a trip type 2.
3. If a stage start is home but the immediate stage that follows it does not return home then it is classified as a trip type 3.
4. Likewise, if the stage end is home but the preceding stage is not start from home then it is classified as a trip type 4.
5. Trip Type 5 is classified if neither that stage start nor the stage end is home.

2.2.7 Table 4 shows the allocation of SHS to SRTM aggregate modes. The 4 aggregate modes used are Car, Walk, PT and Cycle. A further 'Special Public Transport' mode was used to identify trips by school/works buses, which were excluded from the analysis.

Table 4. Allocation of SHS Modes to SRTM Aggregate Modes

SHS MODE	SIMPLE MODE
Car/van as passenger	Car
Car/van as driver	Car
Walking	Walk
Ordinary (service) bus	PT
Bicycle	Cycle
Taxi/minicab	Car
Ferry	PT
Train	PT
Other	PT
Underground	PT
Aeroplane	Ignore
School bus	Spec PT
Works bus	Spec PT
Motorcycle/moped	Car
No answer	Ignore

2.2.8 Table 5 outlines the lookup used when deriving the journey purpose within the SRTM. It shows the grouping of the SHS defined purpose to an equivalent that is used in the demand model. The purposes are Employer's Business (EMP), Commute (COM), Education (EDU) and Other (OTH).

2.2.9 From the defined list of purposes, it can be seen from the table that an additional purpose of 'Home' has been defined. This is not a purpose in its own right, though it is used to identified the trip type and subsequently used to identified the Non Home Base purposes (Non Home Based Other & Non Home Based Employer's Business). The trip type is defined in Section 2.2.5.

Table 5. SHS General Purpose Lookup

SHS DESCRIPTION	SRTM PURPRPOSE
School/college/university	EDU
Returning home from - School/college/university	EDU
The shops	OTH
Home	Home
Your meeting	EMP
Returning home from - Your meeting	EMP
Take the dog out	OTH
Returning home from - Take the dog out	OTH
Returning home from - The shops	OTH
Your friends	OTH
Returning home from - Your friends	OTH
The Council offices	OTH
Returning home from - The Council offices	OTH
Work	COM
Returning home from – Work	COM
Place of worship e.g. church, mosque	OTH
Returning home from - Place of worship e.g. church, mosque	OTH
Volunteering/caring	OTH
Returning home from - Volunteering/caring	OTH
The Hospital	OTH
Returning home from - The Hospital	OTH
The Doctors	OTH

SHS DESCRIPTION	SRTM PURPRPOSE
Returning home from - The Doctors	OTH
School/nursery	EDU
Your day trip	OTH
Returning home from - Your day trip	OTH
Your walk	OTH
Your relatives	OTH
The restaurant	OTH
Returning home from - The restaurant	OTH
Another entertainment/public activity	OTH
Other	OTH
Returning home from – Other	OTH
Another personal appointment	OTH
Returning home from - Another personal appointment	OTH
The park	OTH
Returning home from - Your walk	OTH
Escort – other	OTH
Returning home from - Escort - other	OTH
Returning home from - Your relatives	OTH
Other medical related e.g. dentist, physio	OTH
Participating in sport/exercise	OTH
Returning home from - Participating in sport/exercise	OTH
Returning home from - Another entertainment/public activity	OTH

SHS DESCRIPTION	SRTM PURPRPOSE
The pub	OTH
Returning home from - The pub	OTH
Returning home from - School/nursery	OTH
University	OTH
Returning home from - University	OTH
The bank	OTH
Returning home from - The bank	OTH
Returning home from - The park	OTH
The gym	OTH
Returning home from - The gym	OTH
The cinema	OTH
Returning home from - The cinema	OTH
Your run	OTH
Returning to workplace from - The shops	OTH
Returning home from - Other medical related e.g. dentist, physio	OTH
Returning to workplace from - Your meeting	EMP
Returning to work after a series of calls	EMP
College	OTH
Returning home from - College	OTH
Your cycle	OTH
Returning home from - Your cycle	OTH
Returning to workplace from - Other	OTH

SHS DESCRIPTION	SRTM PURPRPOSE
School	EDU
Your drive	OTH
Returning home from - Your run	OTH
Returning home from - Your drive	OTH
Returning home from – School	EDU
On holiday	OTH
Returning home from - On holiday	OTH

2.2.10 The final journey purpose, Retired (RET), uses the economic status of the individual (namely those declaring themselves to be "Permanently retired from work") to allocate all of their trips to a 'Retired' journey purpose, to allow the subsequent modelling within the SRTM to reflect the different mode preferences, values of time and availability of concessionary travel for this segment of the travel demand.

2.2.11 The SHS dataset is based on the random adult stages defined where individuals are aged 16 or older, therefore it should be noted that the education trips outlined within this dataset has a strong bias towards tertiary and under-representing the primary and secondary trips. This dataset does not provide sufficient information for robust proportions for the education demand segments.

2.2.12 In light with the observations made above, the education purpose was re-defined such that only children less than equal to 16 year old would be considered to have an 'Education' purpose. The others fall into the 'Other' category. Thus, in this dataset all the education trip was re-assigned to other.

2.2.13 The 2011 census data has been used to derive the education mode share using the "Method of Travel to Study by Age" data, while the 2011 pupils census data has been used to obtain education origin destination movements for trip length / cost analysis. It is also further assumed that all of this trips can be considered as simple home based trips.

2.2.14 Further, it is assumed to established that the outbound trip will be in the AM and the inbound trip will be in the 2nd inter-peak School Run (SR).

2.2.15 In addition to the compilation of the general purposes and mode of transport, the trips were allocated to Car Available (CAV) and No Car Available (NCA) as follows.

2.2.16 The SHS dataset give information on the number of cars owned per household which is used to derive the car availability for a given stage. The methodology is outlined below.

1. Firstly, if the number of cars per household is greater or equal to the number of adults in the household, it is assumed to have a CAV of 1.
2. An assumption is made such that if a household does not have any cars, there is no car available for any of the trips made by members of that household.
3. A CAV and NCA proportion is applied as per Table 6 if the number of cars is less than the number of adults in the household.
4. If the number of car per households exceeds or is equal to the number of adults the CAR proportion is deemed to be equal to one and the NCA proportion is equal to zero.

Table 6. Car Available and No Car Available Proportion

SRTM PURPOSE	CAV PROPORTION	NCA PROPORTION
EDU	0.2	0.8
OTH	0.5	0.5
EMP	0.8	0.2
COM	0.7	0.3

2.2.17 It is worth noting that the purpose of the above proportions is simply to provide an initial split of trips where there is competition for the use of the available vehicle. The calibration of mode destination choice will adapt the mode constants to correct for any error in these assumed proportions.

2.2.18 The combination of the car availability, mode and the general purposes allowed the expansion of the general purposes to 10 demand segments the STRM model uses. These demand segments were used for the Simple and Non Simple Tours.

2.2.19 In order to represent the non-home based trips, the entries with a Trip Type 5 (described above) were split between either Employer's Business or Other. By evaluating the car availability, this resulted in 4 more demand segments.

2.2.20 The dataset was further disaggregated by time period in order to capture the variations in movements. Table 7 shows the time period allocation lookups used. The mid-point time for each individual stage was calculated with each stage allocated a time period based on the time period groups below – Morning peak (AM), Lunchtime (LT), School Run (SR), Afternoon Peak (PM), Evening Off peak (OP).

Table 7. SHS Time Period Lookup

START TIME	FINISH TIME	TIME PERIOD	NAME
00:00	07:00	5	OP
07:00	10:00	1	AM
10:00	13:00	2	LT
13:00	16:00	3	SR
16:00	19:00	4	PM
19:00	00:00	5	OP

2.2.21 Following this, a review of the SHS data was performed to identify records to be cleaned from the analysis.

2.2.22 In its original format there were 24,215 stages and after the cleaning process the final count of the useful stages was 17,465 which represents a reduction of 28%. Table 8 below shows the breakdown of the 'lost' trips. It can be seen that the majority of the trips removed were due to them appearing in the weekend which is not relevant for this model.

Table 8. SHS Deleted Records Summary

REASON FOR REMOVAL	RECORDS	PERCENTAGE
Removed Saturday and Sunday	5404	80.06%
Remove incomplete tours (From home trips <> To Home trips)	1256	18.61%
Mode	3	0.04%
Short trip to main mode	46	0.68%
Home - Home Round Trip	25	0.37%
Non Simple TH trips only - no FH equivalent	2	0.03%
Home to Home purpose defined as SHB	14	0.21%

2.2.23 In addition, the cleaning process ensure that the number of from home trips and the number of to home trips (both simple and non-simple) were balanced. For example, recording of a stage as a 'to home' trip where no 'from home' equivalent has been recorded.

2.2.24 Further, trips which were an extension of a simple tour were removed. For example, recording of a stage of a walk trip to a station.

2.2.25 The aim of this was to organise the data set such that simple home based pairs, non-simple home based pairs and non-home based trips were obtained.

2.2.26 Final output of the SHS processing can be seen in Table 9 below.

Table 9. SHS Trips Summary

TRIP TYPE	COUNT	CAV WEIGHT	NCA WEIGHT	COUNT	CAV WEIGHT	NCA WEIGHT
SIMPLE FH	6,446	4,930	1,545	37%	37%	37%
SIMPLE TH	6,446	4,972	1,503	37%	37%	36%
NON-SIMPLE FH	1,258	983	302	7%	7%	7%
NON-SIMPLE TH	1,258	1,009	276	7%	7%	7%
NHB	2,057	1,569	505	12%	12%	12%
TOTAL	17,465	13,463	4,131	100%	100%	100%

2.2.27 As part of the cleaning process the purposes lookup described above had to be adjusted further as it was noted that escort to education trips were combined with education in the dataset.

2.2.28 This was carried out by evaluating the economic status of the trip previously classified as education trips. It showed that 43% of the education trips were by individuals that stated they were in full time employment, retired, unemployed and home duties.

2.2.29 In order to rectify the over allocation of trips to education, it was initially assumed that only trips where the stated purpose was education and the economic status of the individual were student was considered to have education the trip purpose.

2.2.30 Furthermore, a trip was reallocated to the 'Other' purpose category if an education trip was followed within 35 minutes by a subsequent trip as this suggested the first trip was an adult escorting a child to education trip.

2.2.31 The trips identified as likely to be 'Escort to Education' were reallocated to the 'Other' purpose category.

Tour Proportions

2.2.32 The initial time period classification was further expanded as the STRM uses tours. Tours are two way trips that go outbound (From-Home) in a given time period and return (To Home) in a given time period. The tours only apply for simple to/from home trips and are presented in Table 10.

Table 10. Tour Grid References

	INBOUND TIME PERIOD					
OUTBOUND TIME PERIOD		AM	LT	SR	PM	OP
	AM	1	2	3	4	5
	LT	6	7	8	9	10
	SR	11	12	13	14	15
	PM	16	17	18	19	20
	OP	21	22	23	24	25

2.2.33 Table 12 below outlines the tour proportions derived from the SHS dataset. An overnight tour is where the 'to home' leg is in an earlier time period than the 'from home' leg and is not modelled and thus set to zero.

2.2.34 Tour proportions for different geographic regions was evaluated as part of the SHS processing in order to evaluate if there was a need to use different tour proportions. Therefore a 'Z-Test' which is a statistical test to evaluate if two samples are difference from each other was undertaken (details in Appendix B). The tour proportions were calculated for 4 different movements, as follows:

1. Glasgow City to Rest of the modelled area;
2. Rest of the modelled area to Glasgow City;
3. Rest of the modelled area to Rest of the modelled area; and
4. Glasgow City to Glasgow City.

2.2.35 Following these test there were not a significant difference to justify the uses of different tour proportions. The only exception within this analysis was the Education trips, however as the number of trips were very small it was discarded as it didn't provide a valid representation. Table 11 below shows the number of education trips in the SHS.

Table 11. Number of Education trips in SHS

	TOUR 1	TOUR 2	TOUR 3	TOUR 4
EDU_CAV	28	43	91	76
EDU_NCA	59	68	50	40

2.2.36 Additionally, as stated above the SHS dataset is based on the random adult assumption, where only students who are aged 16 or over are represented. Therefore, it is not a robust evidence base for selecting different tour proportions in different areas for full set of all-age education trips.

2.2.37 Further to the tour proportions, specific Park and Ride tour proportions were derived which will be used for setting up the Park and Ride model. These will be reported through the Park and Ride technical note.

Table 12. Tour Proportions

TOURS [1]	EMP CAV	EMP NCA	COM CAV	COM NCA	OTH CAV	OTH NCA	EDU CAV	EDU NCA	RET CAV	RET NCA
1	2.4%	0.0%	0.1%	0.8%	5.4%	6.4%	0.0%	0.0%	6.1%	7.4%
2	3.4%	0.0%	1.7%	3.8%	5.4%	4.7%	0.0%	0.0%	8.7%	7.5%
3	16.7%	0.0%	9.9%	12.2%	4.2%	7.7%	100%[2]	100%[2]	2.3%	2.1%
4	37.2%	0.0%	51.3%	39.0%	2.5%	4.0%	0.0%	0.0%	1.5%	0.4%
5	2.9%	0.0%	5.0%	3.8%	0.5%	0.9%	0.0%	0.0%	0.3%	0.4%
6	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
7	4.2%	0.0%	0.0%	0.0%	10.4%	13.4%	0.0%	0.0%	16.3%	21.7%
8	4.5%	0.0%	1.1%	2.1%	9.8%	11.8%	0.0%	0.0%	14.2%	18.4%
9	5.9%	0.0%	3.0%	4.8%	3.1%	5.5%	0.0%	0.0%	5.1%	5.3%
10	1.6%	0.0%	2.4%	7.7%	0.5%	2.2%	0.0%	0.0%	0.6%	0.3%
11	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
12	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
13	1.0%	0.0%	0.2%	0.5%	13.5%	13.4%	0.0%	0.0%	13.6%	14.3%
14	3.7%	0.0%	1.4%	2.1%	5.7%	7.3%	0.0%	0.0%	13.3%	9.6%
15	2.7%	0.0%	3.6%	4.9%	0.9%	2.0%	0.0%	0.0%	1.1%	1.1%
16	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
17	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
18	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
19	1.1%	0.0%	0.2%	0.0%	9.2%	6.1%	0.0%	0.0%	6.1%	3.5%
20	5.0%	0.0%	2.1%	3.8%	14.0%	6.5%	0.0%	0.0%	5.9%	1.9%

[1] As defined in Table 8

[2] See section 2.2.13

TOURS [1]	EMP CAV	EMP NCA	COM CAV	COM NCA	OTH CAV	OTH NCA	EDU CAV	EDU NCA	RET CAV	RET NCA
21	0.0%	0.0%	0.3%	0.6%	0.1%	0.1%	0.0%	0.0%	0.3%	0.5%
22	0.2%	0.0%	0.9%	1.8%	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%
23	0.8%	0.0%	6.0%	6.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%
24	3.7%	0.0%	9.0%	4.7%	0.3%	0.2%	0.0%	0.0%	0.1%	0.0%
25	3.0%	0.0%	1.9%	1.4%	13.8%	7.7%	0.0%	0.0%	4.6%	5.1%

Time Period Proportions

2.2.38 The time period proportions were derived from the SHS in order to establish the starting time period of the Non Simple tours and Non-Home Based trips. This is outlined in Table 13 and Table 14.

2.2.39 The Non Simple Home Based tours the these proportions was derived for the 10 demand segments similarly to the above tour proportions.

2.2.40 The Non Home Based trips proportions were derived for Employer's Business and Other split by car availability. Thus, this produced 4 demand segments for the non-home based trips outlined as:

- Non Home Based Employer's Business Car Available (NHBEB CAV);
- Non Home Based Employer's Business No Car Available (NHBEB NCA);
- Non Home Based Other Car Available (NHBO CAV); and
- Non Home Based Other No Car Available (NHBO NCA)

Table 13. Time Period Proportions Non Simple Home Based Tours

	EMP CAV	EMP NCA	COM CAV	COM NCA	OTH CAV	OTH NCA	EDU CAV	EDU NCA	RET CAV	RET NCA
AM	33%	0%	52%	38%	19%	21%	100%[3]	100%[3]	16%	12%
LT	12%	0%	5%	5%	14%	25%	0%	0%	33%	44%
SR	13%	0%	4%	15%	18%	20%	0%	0%	27%	29%
PM	30%	0%	18%	18%	27%	21%	0%	0%	18%	12%
OP	12%	0%	21%	24%	22%	13%	0%	0%	7%	3%

[3] See section 2.2.13

Table 14. Time Period Proportions Non Home Based

	NHBEB CAV	NHBEB NCA	NHBO CAV	NHBO NCA
AM	29%	0%	18%	17%
LT	28%	0%	20%	22%
SR	23%	0%	25%	29%
PM	20%	0%	30%	22%
OP	0%	0%	8%	11%

Mode Shares

2.2.41 Mode share by demand segment was established from the SHS data. The mode shares have been split into the to/ from home (employer's business, commute, other, education, and retired) and the non-homed based trip (employer's business and other).

Table 15. SHS Mode Shares

	CAR AVAILABLE TRIPS				NO CAR AVAILABLE TRIPS			
	CAR	PT	WALK	CYCLE	CAR	PT	WALK	CYCLE
EMP	88.3%	6.5%	5.2%	0.0%	0.0%	0.0%	0.0%	0.0%
COM	86.3%	6.4%	6.4%	0.9%	0.0%	56.5%	40.3%	3.2%
OTH	82.8%	3.6%	13.3%	0.3%	0.0%	30.2%	68.2%	1.6%
EDU	26%	22%	51%	1%	0.0%	30%	69%	1%
RET	83.9%	3.4%	12.4%	0.4%	0.0%	46.0%	53.6%	0.5%
NHBEB	63.5%	23.9%	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%
NHBO	69.1%	16.3%	14.3%	0.3%	0.0%	46.8%	52.7%	0.5%
TOTAL	82.6%	6.1%	10.9%	0.5%	0.0%	39.8%	58.7%	1.5%

Car User / Car Driver factors

2.2.42 These factor are the proportion of car user (passenger) to the car driver. This has been derived by evaluating the modes at each stage. Table 15 outlines the lookup for the different modes and it shows that in each stage the distinction between car driver and car passenger is made. These are used in order to calculate the proportion which is shown in Table 16. It should be noted that since the children under the age or 16 are not represented in this dataset these factors have underestimated the CDCU factors.

Table 16. Car User/ Car Driver proportions

	AM	LT	SR	PM	OP
EMP	1.13	1.08	1.08	1.14	1.08
COM	1.13	1.09	1.20	1.14	1.19
OTH	1.23	1.29	1.25	1.31	1.43
EDU	1.64	1.64	1.64	1.64	1.64
RET	1.24	1.34	1.49	1.41	1.50

2.2.43 The CDCU factors for education was sourced from DfT National Travel Survey information (Table NTS0906). The factor was derived using the following methodology:

- Obtain an average car occupancy of 2.06 from table NTS0906
- Obtain a single occupancy rate of 36% from table NTS0906
- Thus 64% of Education trips are multi-occupancy
- Of the average, the single occupant trips represent 0.36 of the 2.06
- Thus the 64% multi-occupant trips represent 1.7 of the 2.06.
- Divide 1.7 by 0.64 to yield an average occupancy of 2.64 for the multi occupancy trips

2.2.44 The resulting average occupancy was 2.64, this was reduced by one (the car driver) to reflect the definition of Education trips being only the pupils matrices. The driver does not form part of the education trips within the demand model as the trip end model supplies the student / child trip to education. The average occupancy is used to convert these person trips to the equivalent car trip for the road assignment model.

Trip Length / Cost Distributions

2.2.45 Trip matrices were extracted from the SHS for the 14 demand segments and the 4 modes (Car, PT, Walk, Cycle) by datazone. It should be noted that the SHS dataset was obtained with the 2001 datazone.

2.2.46 These datazone to datazone zone movements were then converted to the equivalent SRTM zoning system. This data, in combination with travel cost and distance skims from the prevailing model, will be used to derive trip length and trip cost distributions to calibrate the demand model.

2.3 Census Journey to Work

2.3.1 Data from the census was received in the form of Census Travel to Work movements as origin to destination zone pairs with the following geographic structures covering the extent of Scotland:

- Datazone zones within the SRTM modelled study area; =
- Intermediate zones for the local authorities lying adjacent to the SRTM modelled study area; and
- Local Authority based geography beyond this.

2.3.2 However, there were special destination codes representing the following, together with the action taking regarding the data:

- OD0000001 = Mainly work at or from home, action was re-mapping of destination zone to origin zone;
- OD0000002 = Offshore installation, action was to disregard data;
- OD0000003 = No fixed place, action was to disregard data; and
- OD0000004 = Outside UK, action was to disregard data.

2.3.3 Three separate files were received, one file for each car availability segment of "no car available", "one car, more adults" and "cars available". Each file had five classifications of travel mode, from which we selected Public Transport, Driving a car or van and Passenger in a car or van to include as PT or Car mode in subsequent analysis.

2.3.4 The data was translated into the SRTM zoning system for all movements within the SRTM modelled area. This was achieved through proportions derived from the population and employee numbers for home and place of work accordingly.

2.4 Road Traffic Counts

2.4.1 Road traffic counts were used to create the time period to modelled hour factors used within the Assignment Preparation stage. These have been reported within the road model development note.

2.5 Public Transport Factors

2.5.1 Public transport passenger counts were used to create the time period to modelled hour factors used within the Assignment Preparation stage.

2.5.2 The Passenger Demand Forecasting Handbook was used to source ticket type proportions to convert the Commute and Other demand matrices into Season and Standard tickets.

2.5.3 These have been reported within the public transport model development note.

2.6 Mobile Phone Data Processing

2.6.1 The demand model has made use of mobile phone data to enable a validation check of the matrices output by the demand model by journey purpose at varying sector systems.

2.6.2 The analysis of the data has been reported through a separate technical note reporting the mobile phone data testing and subsequent analysis.

2.7 Parking Model Data

2.7.1 The source and processing of data relating to the parking models is detailed in Chapter 5.

2.8 Park and Ride Model Data

2.8.1 The source and processing of data related to the park and ride model is discussed in Chapter 6.

3. MODE AND DESTINATION CHOICE MODEL

3.1 Overview

3.1.1 The mode and destination choice module is the core component of the demand model. Its essential function is to replicate the choices (of mode and destination) that a traveller will make when undertaking a journey for a particular purpose, given that they will be travelling at a particular time of day (considering both outbound and inbound time periods).

3.1.2 This component will purely consider simple tours i.e. those tours which have a return home trip from the same initial destination. A separate One-Way model will be built to handle the individual legs of a non-simple tour, which will in practice work identically to the standard Mode and Destination Choice model with the exception that it will focus on time periods, not tours.

3.2 Inputs

3.2.1 The inputs to this model will consist of the From-Home trip ends and (average) generalised cost matrices. The trip ends are defined for each tour (25) and demand segment (9) and include productions and attractions.

3.2.2 As well as the simple tour trip ends, within the One-Way model the one-way trip ends will be read in for all demand segments (12) and time periods (5).

3.2.3 As noted previously, there are only five sets of average distinct generalised costs matrices by time period as there are a reduced number of user classes in the assignment models i.e. the costs for corresponding car available and non-car available demand segments are identical.

3.2.4 In the first loop these inputs come from the 'Initialise' element of the model, but on subsequent loops the generalised cost inputs change, with new costs becoming derived initially in the assignment models, and subsequently adjusted in the 'Generalised Costs' model to account for parking and combined modes such as Park and Ride. The trip ends which enter this stage of the model are kept constant throughout a model run.

3.2.5 The model will also include an estimation of parking charges which are read in via a table corresponding to each tour and are denominated in pounds. The model will automatically converts these charges into generalised minutes using a specific value of time for each user class. This value of time should change annually to account for forecast growth in the Value of Time. In deriving tour specific parking charges, the following assumptions will be used:

- Intra-tour parking charges are to be taken as half the duration of the time period (1.5 hours) times the hourly parking charge;
- Inter-tour parking charges are to be taken as the length of time between the middle of each tour (therefore a multiple of three) times the hourly parking charge;
- Tours which have an outbound trip in the off-peak will be considered as free parking; and

- One-Way trips (which have no link to any later trips) are assumed to enter and leave within the same time period and therefore have 1.5 hours duration.

3.3 Outputs

3.3.1 The outputs of the mode and destination choice model will be the end to end trips by tour for each mode and aggregated demand segment (user class). Although there will be a total of 125 tables for each demand segment, since the demand model does not require a further split by car availability the user classes can be aggregated at this point to reduce the number of tables and files to be dealt with later in the model.

3.3.2 As Free Work Place Parking will have a significant impact on both mode and destination choice within the commute demand segments, there will be no benefit in aggregating these demand segments at this stage and they will instead be output as two separate files by demand segment, disaggregated by car availability and containing 125 tables noting demand for each of 25 tours and 5 modes.

3.3.3 It is noted that for these demand segments in particular the demand will reflect no Parking Charges being paid at this stage.

3.4 Mathematical Framework

3.4.1 Mode and destination choice is represented using a two level nested logit hierarchy with destination taken to be conditioned on mode choice as shown below in Figure 4. This assumes that mode is before destination as is consistent with previous LATIS models which have covered the model area, but now includes active modes.

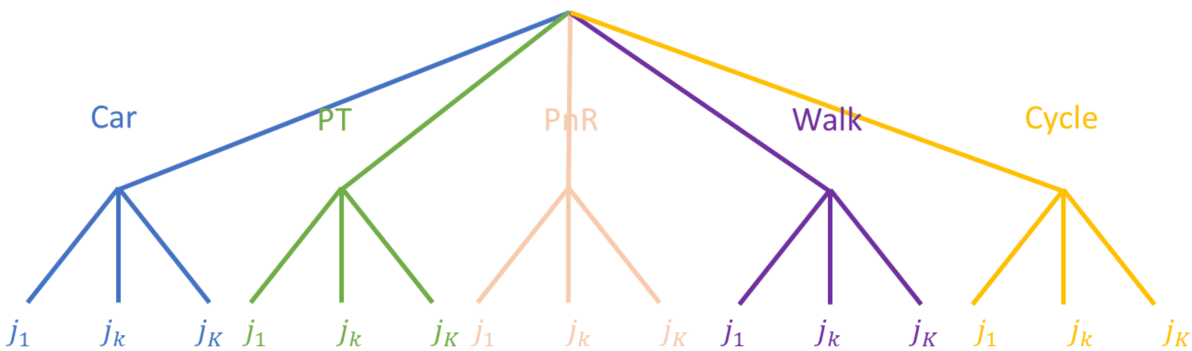


Figure 4. **Mode and Destination Choice Hierarchy**

3.4.2 It is noted that on the lowest level (destination choice after mode), only three representative choices are shown but actually every destination is compared and as such the number of choices is equal to the number of zones.

3.4.3 In order to model the choices, the concept of utility is used where utility is defined on the lowest levels of the hierarchy as

$$V_{mij} = \alpha U_{mij} + \beta \ln(U_{mij}) + IZM + ASC_m$$

Where:

V_{mij} is the mode specific utility to be used in the destination choice logit comparison;

U_{mij} is the mode specific generalised cost between i and j (based on assignment skims);
$IZM_m = 0$ if $i \neq j$ is an estimated intrazonal parameter;
ASC_m is the mode specific alternative specific constant; and
α, β are estimated parameters.

3.4.4 These utilities are compared in a logit choice model to estimate the probability of making each choice, in this case destination, by comparing all available destinations to find

$$P_j = \frac{K_J A_J e^{\lambda V_{ij}}}{\sum_{j \in J} K_J A_J e^{\lambda V_{ij}}}$$

Where:
$\lambda < 0$ is the relevant spread parameter;
V_{ij} is the utility from zone i to destination choice j;
A_J is the attraction weighting for destination zone J;
K_J is the K factor attributed to destination zone J; and
J is the subset of choices considered, in this case each destination by mode.

3.4.5 For mode choice, the utility is defined as the composite cost which is calculated as the logsum of the destination choice levels. For instance, the walk mode utility is calculated as

$$U_{walk\ i} = \frac{1}{\lambda_{Dest}} \ln\left(\sum_{j \in J} B_j e^{\lambda_{walk} U_{Walk\ ij}}\right)$$

Where
$U_{walk\ i}$ is the composite cost of walking for a zone i;
B_j is the proportion of attractions for zone j;
$\lambda_{Dest} < 0$ is the destination mode choice spread parameter;
k is a zone within the full set of zones K; and
$U_{walk\ ij}$ is the utility of walking between i and j.

3.4.6 In practice, this involves deriving the total number of modal trips leaving each zone i.e. the productions, while the attractions will be assumed to be equally likely by any mode. How this is applied following the calculation of proportions depends upon whether the demand segment is a doubly constrained or singly constrained journey purpose. This is defined below in Table 17.

3.4.7 For singly constrained journey purposes, the probability of choosing a destination will be calculated separately for each zone and mode at the production end. This proportion is then factored by the total productions for each zone. The attractions are effectively used as proportions to distribute the trips whereby the attractions are balanced to the productions at a trip end level. These are undertaken at a tour level for each demand segment.

3.4.8 For doubly constrained journey purposes there is a requirement to generate a trip attraction value to constrain to. The utility is calculated for both productions and attractions for these. WebTAG guidance indicates that commuting and education purposes should be doubly constrained, as there is good evidence from data on both the productions and attractions (Unit M2 – Para 4.9.3).

3.4.9 However, for SRTM given the multiple data sources that have informed the education trip purpose, we do not consider that we have a sufficiently robust set of attractions on which to base a doubly constrained model.

Table 17. Demand Segment Constraint

REF	PURPOSE	RETIRED STATUS	CAR AVAILABILITY	CONSTRAINED
1	EMP	Non-Retired	All	Single
2	COM	Non-Retired	Car available	Double
3	COM	Non-Retired	No car available	Double
4	OTH	Non-Retired	Car available	Single
5	OTH	Non-Retired	No car available	Single
6	EDU	Non-Retired	Car available	Single
7	EDU	Non-Retired	No car available	Single
8	ALL	Retired	Car available	Single
9	ALL	Retired	No car available	Single
10	EMP	All	All	Single
11	Not EMP	All	Car available	Single
12	Not EMP	Non-Retired	No car available	Single
13	EMP	Non-Retired	All	Single
14	COM	Non-Retired	Car available	Double
15	COM	Non-Retired	No car available	Double
16	OTH	Non-Retired	Car available	Single
17	OTH	Non-Retired	No car available	Single
18	EDU	Non-Retired	Car available	Single
19	EDU	Non-Retired	No car available	Single
20	ALL	Retired	Car available	Single
21	ALL	Non-Retired	No car available	Single

3.4.10 The use of tours within the SRTM also presents computational issues when considering a doubly constrained model.

3.4.11 Conventionally this would be achieved by balancing the productions against the individual mode / car availability segmented productions, and then combining these matrices to balance against the total attractions, as the trip end model attractions are not segmented.

3.4.12 Within SRTM, our 25 tours, 5 modes and 2 car availabilities results in 250 matrices to aggregate to balance against total attractions.

3.4.13 Following this, the resulting attraction constrained matrix would have to be disaggregated into the component mode / car availability for the next loop of production balancing. After this the process would continue looping through these steps until convergence.

3.4.14 Clearly, this would result in significant run time penalties when operating with 250 matrices, as well as reaching the limits of Cube MATRIX software. While it may be possible to only consider "true" tours in this approach this itself would only result in a marginal reduction in matrices.

3.4.15 Consequently, we have adopted a different approach which retains consistency with the mode destination choice model to apply weights to the attractions to convert from "all" modes attractions to mode specific attractions.

3.4.16 This has been done by applying the same equation as 3.4.4 above, only multiplying by production weights and summing over the column rather than row (i.e. over attraction j rather than production i).

3.4.17 The resulting mode splits by attraction j are then applied to the trip end outputs to convert from an "all" attraction into a mode specific trip attraction. The public transport attractions are then further weighted by K factors for central area zones.

3.4.18 These attractions are then weighted to ensure that they match the production level and are then passed to the Cube FRATAR process to doubly constrain.

3.4.19 Through operation of the model, it became apparent that significant mode constants would be required to ensure that the observed cycle mode share was reproduced. In order to improve the model's ability to forecast changes in the cycling mode, a factor representing the level of cycle ownership has been included within the model. The final approach can be visualised in Figure 5 below:

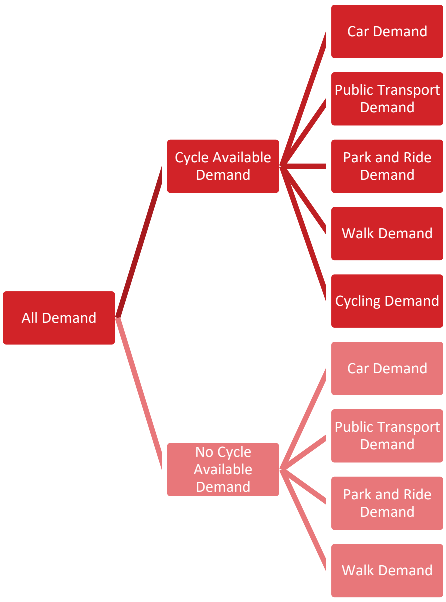


Figure 5. **Adjusted Mode Choice Model Structure**

3.4.20 For those people who have access to a bicycle (assumed to be proportional to bicycle ownership), the full range of choices is available. While for those without access to of a bicycle, the reduced option set is used.

3.4.21 In this way, the mode shares of cycle use can be better calibrated, and potentially sensitivity based testing of policies to promote cycling can be incorporated into the model.

3.4.22 Data on bicycle ownership was sourced from the Scottish Household Survey, specifically Table 8 of the SHS Transport: Local Area Analysis 2014.

3.4.23 The percentage of households that have zero bikes available for private use was sourced for each of the 11 local authorities within the SRTM model area, with the appropriate local authority value appended to a zone record based on which local authority the zone was within. Table 18 documents the base year cycle ownership:

Table 18. Cycling Ownership

LOCAL AUTHORITY	% OWNING A BICYCLE	% NO BICYCLE AVAILABILITY
Argyll & Bute	43.8%	56.2%
East Ayrshire	34.5%	65.5%
East Dunbartonshire	40.7%	59.3%
East Renfrewshire	29.9%	70.1%
Glasgow City	22.2%	77.8%
North Ayrshire	36.4%	63.6%
North Lanarkshire	25.0%	75.0%
Renfrewshire	34.1%	65.9%
South Ayrshire	31.4%	68.6%
South Lanarkshire	25.1%	74.9%
West Dunbartonshire	32.0%	68.0%

3.4.24 This has been setup as a user input, enabling the model user to change the inputs if required.

3.5 Calibration and Data Requirements

3.5.1 In order to estimate the parameters above, observed generalised cost distributions and mode shares by demand segment will need to be obtained to calibrate against. The primary sources of this data will be the Census Travel to Work data for commute, data for the education demand segments will be sourced from a combination of the pupil census and census travel to place of education, and the Scottish Household Survey for all other demand segments.

3.5.2 Mode share will be obtained directly from the data at a 24 hour level. The generalised cost distributions will be obtained by aligning all observed records with the model zone system and using the generalised cost obtained from the assignment models to generate the distribution. At the same time as obtaining generalised cost distributions, trip length and journey time distributions will also be obtained for comparison although replicating these will not be the primary focus of the calibration.

3.5.3 To match the generalised cost curves and mode shares, various parameters within the utility function will be manipulated independently in an iterative process which will attempt to match the average generalised cost and mode share. This requires that the spread parameters (λ) will be kept constant to reduce the number of variables, and these will be obtained from WebTAG (Unit M2 Section 5.6) in the first instance. Should the realism tests show that these values are unsuitable to produce a reasonable response within the demand model, at that point that spread parameters can be manipulated to improve the model.

3.5.4 The K factors will be calculated based on the observed sectoral attraction share of the census travel to work data. The sector system used is as illustrated below in Figure 6.

3.5.5 Once the Scottish Household Survey data has been segmented into sector movements, there is not sufficient data to base robust proportions on to calibrate K factors. Consequently, we are using the census derived commute values for each demand segment. The K factors only vary by car availability, though it should be noted that the only non-1 value is for public transport to 42 central Glasgow zones.

3.5.6 The absolute numbers as output from the Census travel to work data as shown below in Table 19, with Table 20 providing the target proportions used in calculating K factors.

Figure 6. **K Factor Sector System**

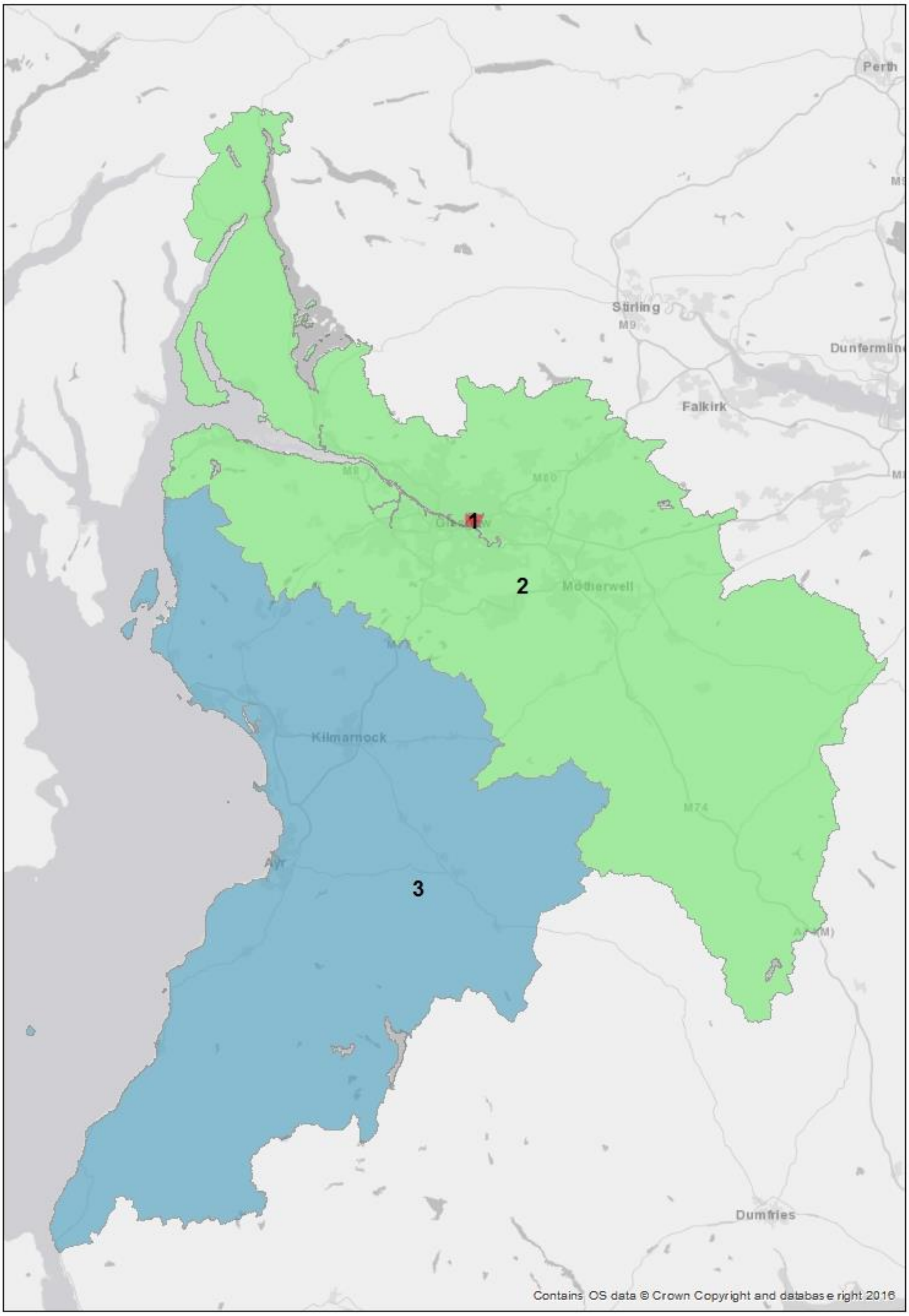


Table 19. Census Sectored Attraction Analysis

MODE CAR AVAILABILITY	SECTOR 1	SECTOR 2	SECTOR 3	ALL
Car Available Car	26511	383793	80838	491142
Car Available Public Transport	44105	41223	5568	90897
Car Available Walk	3769	27600	6783	38152
Car Available Cycle	419	3067	754	4239
No Car Available Car	0	0	0	0
No Car Available PT	24379	49262	6022	79664
No Car Available Walk	5612	27963	4737	38312
No Car Available Cycle	624	3107	526	4257

Table 20. Target Proportions of Census Demand

MODE CAR AVAILABILITY	SECTOR 1	SECTOR 2	SECTOR 3	ALL
Car Available Car	5%	78%	16%	100%
Car Available Public Transport	49%	45%	6%	100%
Car Available Walk	10%	72%	18%	100%
Car Available Cycle	10%	72%	18%	100%
No Car Available PT	31%	62%	8%	100%
No Car Available Walk	15%	73%	12%	100%
No Car Available Cycle	15%	73%	12%	100%

4. FREE WORKPLACE PARKING MODEL

4.1 Overview

4.1.1 In the central Glasgow area there is a significant amount of free workplace parking, however, it is not unlimited and thus a Free Work Place Parking (FWPP) model has been built to replicate the choices that a traveller may face, in particular modelling the likelihood of obtaining a space and making the decision on whether to travel by car if a space is not likely to be available, particularly with respect to parking charges.

4.2 Inputs

4.2.1 The inputs to the initial free workplace parking model are outputs from the mode and destination choice model for the commute demand segments (simple tours only). As well as the modelled inputs, a site file containing a list of free workplace parking spaces by zone is included in the input folder. The derivation of this file is documented in section 4.5.

4.2.2 All costs and parameters which are used in the standard mode and destination choice model for these demand segments are required as following evaluation of access to Free Workplace Parking, a secondary mode and destination choice model is undertaken for these demand segments.

4.3 Outputs

4.3.1 The outputs of this model component are identical in order to mode and destination choice so that they will be compatible with the next phase of the model. Thus they are From Home trips by tour (25) and mode (5).

4.3.2 In addition, the commute trip movements which are modelled as having obtained a free space will be passed through to Tour Aggregation. These trips are not subject to parking distribution as they are deemed to be satisfied through free workplace parking and will be available by time period and direction.

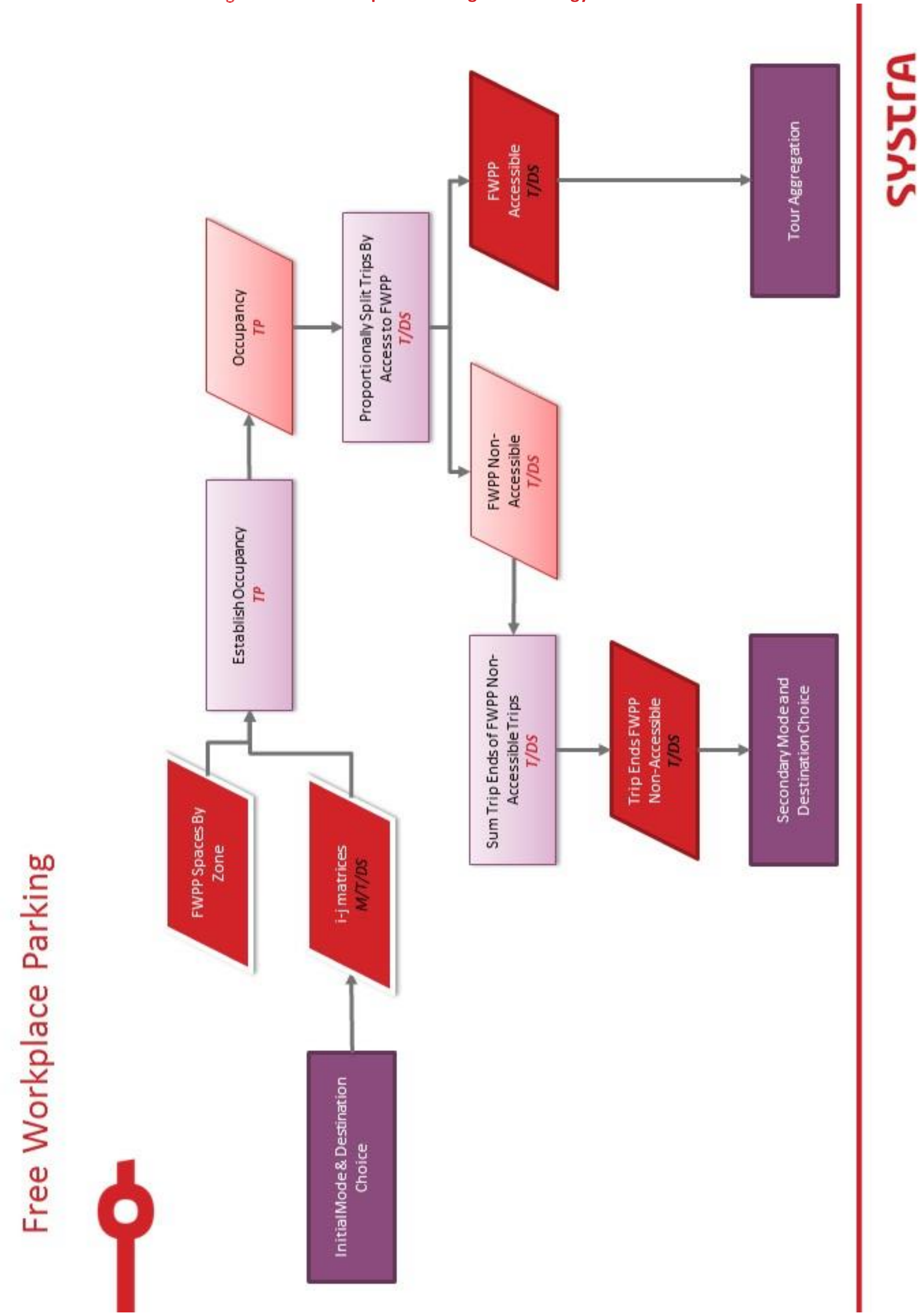
4.3.3 Finally, the model reports the number of free workplace parking spaces which are used in each zone by tour which can then be aggregated externally to establish time period occupancy.

4.4 Mathematical Framework

4.4.1 The process of the Free Workplace Parking model is illustrated overleaf in Figure 7.

4.4.2 The principles behind FWPP are that people will make their travel choices differently dependent on whether there is a free parking space available or not. To account for this, commuters are firstly modelled as evaluating their choices with no parking charge in mode and destination choice i.e. assuming they had access to Free Workplace Parking at their destination.

Figure 7. **Free Workplace Parking Methodology**



4.4.3 The demand for parking is then considered by tour and compared with the supply available to estimate who had access to the free spaces and then these trip are 'frozen' to make sure they do not consider any of the other choices such as Parking Distribution as they are considered to have obtained their first choice. For all other trips, the model will re-evaluate their mode and destination choice with a full parking charge implemented i.e. no access to free parking based on adjusted trip ends which exclude the 'frozen' trips.

4.4.4 It should be noted that in order to model this correctly, the occupancy must be adjusted throughout the day to take account of spaces which have been filled earlier, but the use of tours in this model will allow that to take place with a more robust set of assumptions than otherwise. For clarity, when time period occupancy is being established only the trips which are still present at the end of a time period are included. For example, the AM time period occupancy consists of tours 2, 3, 4, and 5 only (not 1 as they are considered to have left in the AM, based on the tour number in Table 21). Also note that overnights are not included except in the case of OP i.e. the row totals are only summed to the right.

4.4.5 Table 21 shows the tours which are considered to impact on occupancy in each time period (reading across the rows).

4.4.6 A list of the assumptions which are inherent in this model are as follows:

- Free spaces are only available to travellers who originally chose that location as a destination i.e. people who work in that zone, and the secondary destination choice in particular will not be able to offer that space to anyone reconsidering their travel options;
- Each tour within a time period is equally likely to get a obtain a space and there will be no priority given to longer tours for instance;
- The model will assume equal priority for free spaces with no preference for particular trips e.g. longer distance trips will have the same opportunity for a free space as shorter distance trip;
- Trips which will have left by the end of the time period will have no impact on anyone wishing to park during that time period i.e. they are assumed to leave at the beginning of the time period.

Table 21. Free Workplace Parking Tour Grid

TP	Output Time Period
(AM colour)	AM - Morning Peak
(LT colour)	LT – Lunchtime
(SR colour)	SR – School Run
(PM colour)	PM – Evening Peak
(OP colour)	OP – Off Peak

O\I	AM	LT	SR	PM	OP
AM	1	2	3	4	5
LT	6	7	8	9	10
SR	11	12	13	14	15
PM	16	17	18	19	20
OP	21	22	23	24	25

O\I	AM	LT	SR	PM	OP
AM	1	2	3	4	5
LT	6	7	8	9	10
SR	11	12	13	14	15
PM	16	17	18	19	20
OP	21	22	23	24	25

O\I	AM	LT	SR	PM	OP
AM	1	2	3	4	5
LT	6	7	8	9	10
SR	11	12	13	14	15
PM	16	17	18	19	20
OP	21	22	23	24	25

O\I	AM	LT	SR	PM	OP
AM	1	2	3	4	5
LT	6	7	8	9	10
SR	11	12	13	14	15
PM	16	17	18	19	20
OP	21	22	23	24	25

O\I	AM	LT	SR	PM	OP
AM	1	2	3	4	5
LT	6	7	8	9	10
SR	11	12	13	14	15
PM	16	17	18	19	20
OP	21	22	23	24	25

4.5 FWPP Supply Information

4.5.1 The data audit identified two main sources of information for FWPP capacity. These are:

- Glasgow City Council (GCC) survey of Private Non Residential parking (1998); and
- SPT / Glasgow City Centre PNR Parking Data (2010).

4.5.2 Although the GCC survey data is dated, it is by far the most comprehensive survey of private non-residential data. The source of the database is the Assessors files for calculating the rateable value of property.

4.5.3 Consequently, the GCC survey includes other types of parking, with a parking type field within the database. However, not all of the records had the parking type coded. The parking types are listed in Table 22 below, together with the types retained as PnR data.

Table 22. GCC FWPP Parking types

CODE	DESCRIPTION	RETAINED	RECORDS	NUMBER SPACES
98	Car Showrooms	N	19	379
99	Public Parking	N	44	9452
100	Retail Parking	N	9	508
101	Park and Ride Parking	N	4	822
102	Leisure Parking	N	1	1051
103	Office Parking	Y	113	339
	Uncoded	Y	12755	23711

4.5.4 The data has been coded to addresses, in many cases partial addresses and thus geocoding was required. This geocoding was performed based on the location of streets within zones, with appropriate proportioning by length for streets (such as St Vincent Street) that straddle multiple zones.

4.5.5 The aggregated GCC data is as output overleaf in Figure 8.

4.5.6 The SPT data was similarly processed, though as some of the records in this dataset were already geocoded the eastings and northings were used directly. It should be noted though that as the SPT data does not comprehensively cover the city centre, this data source has been used to update the earlier GCC data.

4.5.7 The aggregated SPT data is as output overleaf in Figure 9.

Figure 8. **GCC FWPP Data by Zone**

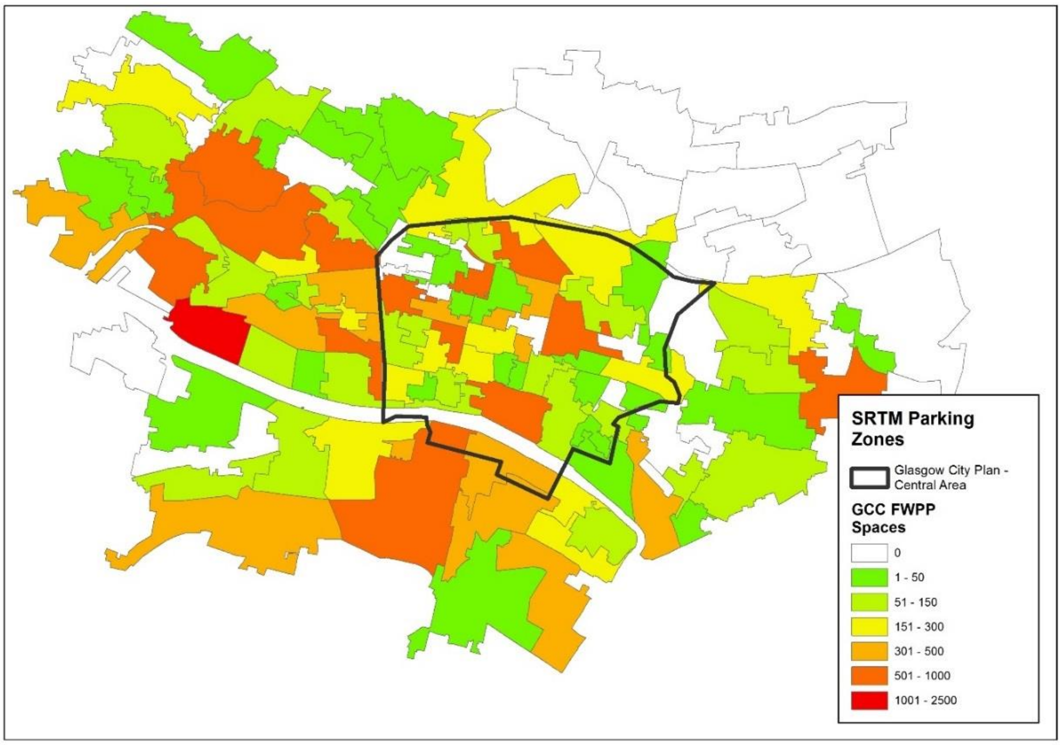
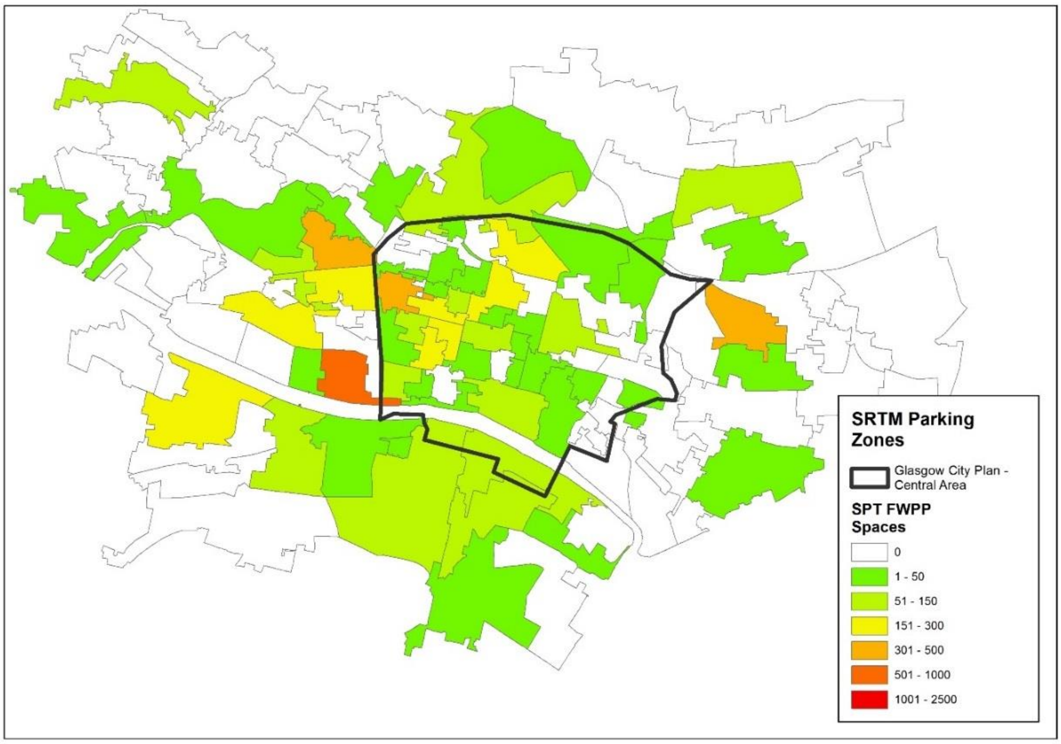


Figure 9. **SPT FWPP Data by Zone**



4.5.8 As can be seen from the above two figures, these data either in isolation or together would result in some zones within the parking area having zero FWPP spaces. Given the non-zero number of jobs in these zones, it is likely that there are some FWPP at these locations. These could either be areas that have not been surveyed, data that has not been recorded, spaces that have been constructed since the survey or simply data that has had their parking type misallocated.

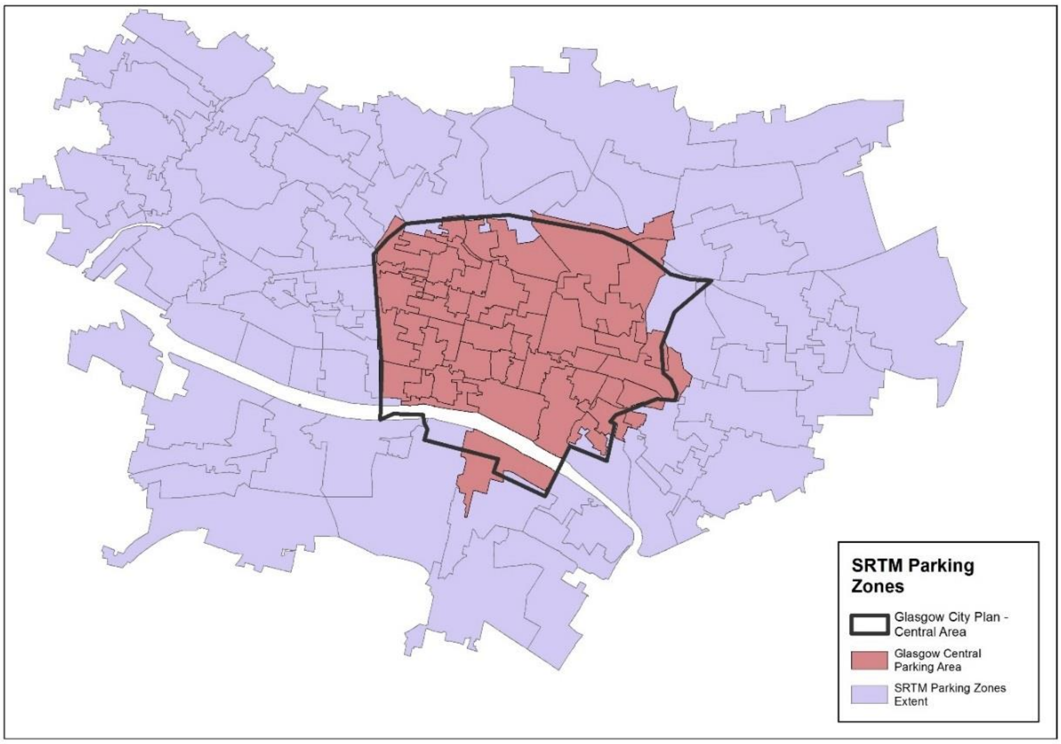
4.5.9 We have reviewed numerous parking documents to provide understanding on the level of FWPP across the central area and its adjacent areas. These documents are listed below:

- Glasgow City Council (GCC) Technical Note;
- Glasgow City Car Park Requirement Scoping Study (2004);
- Glasgow City Centre Parking Review (January 2015);
- Glasgow City Plan 2 documentation (various dates); and
- Glasgow City Air Quality Action Plan – November 2004.

4.5.10 These documents provided a number of estimates of free workplace parking capacity in the 'central' area. We have assumed that the central area matches the definition of the central area in the Glasgow City Plan 2 documentation, and is illustrated as the black boundary line in the figure below.

4.5.11 The figure also illustrates the zones selected to represent the central area within the model, shaded red, with the remaining zones illustrating the extent of the parking model area within the SRTM.

Figure 10. **Glasgow Central area definition**



4.5.12 The table below listed the various free workplace parking space numbers by central and peripheral areas.

Table 23. GCC FWPP Parking types

TYPE	DESCRIPTION	CITY CENTRE	PERIPHERAL
Survey	1987 Survey (reported via Glasgow City Car Park Requirement Scoping Study 2004)	6500	9800
Survey	1995 Structure Plan (reported via Glasgow City Car Park Requirement Scoping Study 2004)	16500	
Survey	1997 Survey (reported via Glasgow City Car Park Requirement Scoping Study 2004)	7239	
Survey	1998 Database	9268	26225
Report	City Plan documentation ("in and around the central area")	18000	
Report	Glasgow Air Quality Action Plan (no defined area)	18000	

4.5.13 To infill data, we have sourced car parking demands from our initial model runs from the SRTM. Although these are uncalibrated numbers, they represent a dataset based on planning data that can be queried to obtain proportions for each zone within the parking area.

4.5.14 Our methodology for infilling data and controlling to the above estimates is as follows:

- Update the database such that the "surveyed" parking data is the higher of the SPT and GCC data;
- For Central Area zones
  - Calculate the proportion of demand for zones in the central area with surveyed parking spaces, defined as [Prop(*sps*)];
  - Calculate the proportion of demand for each zone in the central area with no surveyed parking spaces, defined as [Prop(*zps*)];
  - Divide the surveyed parking capacity across the central area by [Prop(*sps*)] and multiply by [Prop(*zps*)]
- For Peripheral Area zones
  - Calculate the proportion of demand for zones in the peripheral area with surveyed parking spaces [Prop(*sps*)];
  - Calculate the proportion of demand for each zone in the peripheral area with no surveyed parking spaces [Prop(*zps*)];
  - Divide the surveyed parking capacity across the central area by [Prop(*sps*)] and multiply by [Prop(*zps*)]

- Manual updates following application of the above were applied to account for the Shields Road Park and Ride site which had been erroneously included.

4.5.15 The resulting total number of "surveyed" car parking spaces for the central area is 8,776, and for the whole parking area is 24,228.

4.5.16 The resulting total number of car parking spaces post updating for zero zones is for the central area is 9,163, and for the whole parking area is 25,887.

4.5.17 Thus, of the data in the final number of free workplace car parking spaces,94% have been sourced direct from survey, though factored to control totals.

4.5.18 These calculations have been performed within an EXCEL spreadsheet, with the outputs loaded into GIS for viewing and into the FWPP model input files.

4.5.19 Figure 11 illustrates the final free workplace parking numbers, with the subsequent image illustrating the ultimate source data for each zone.

Figure 11. **Free Workplace Parking - Final capacity values**

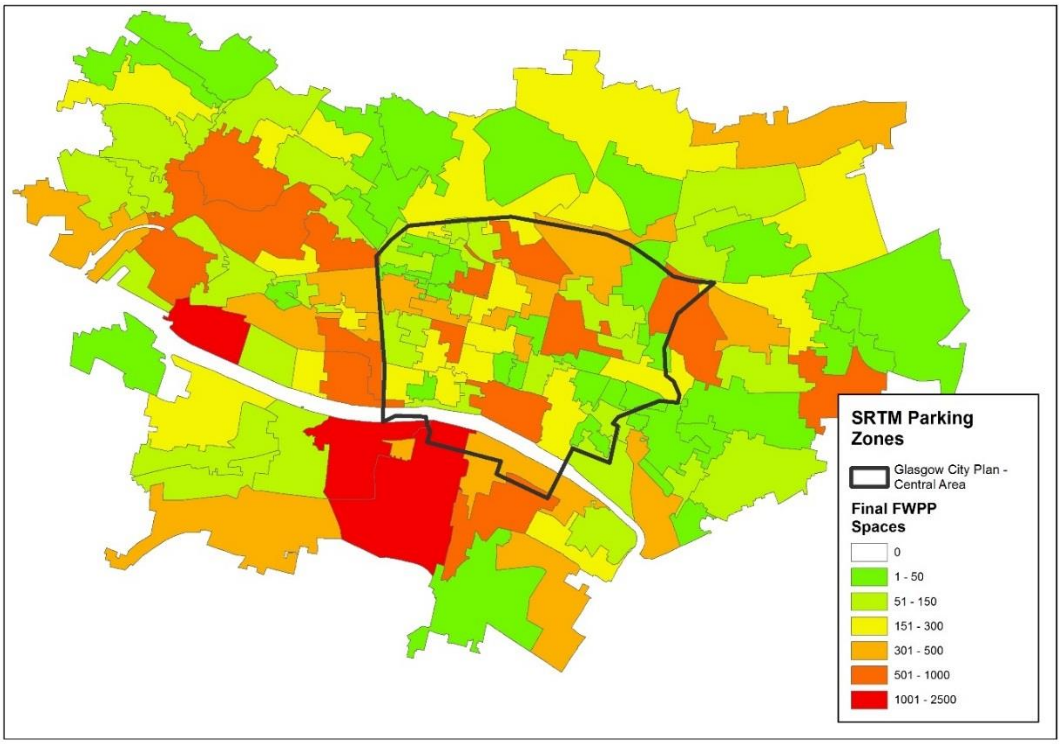
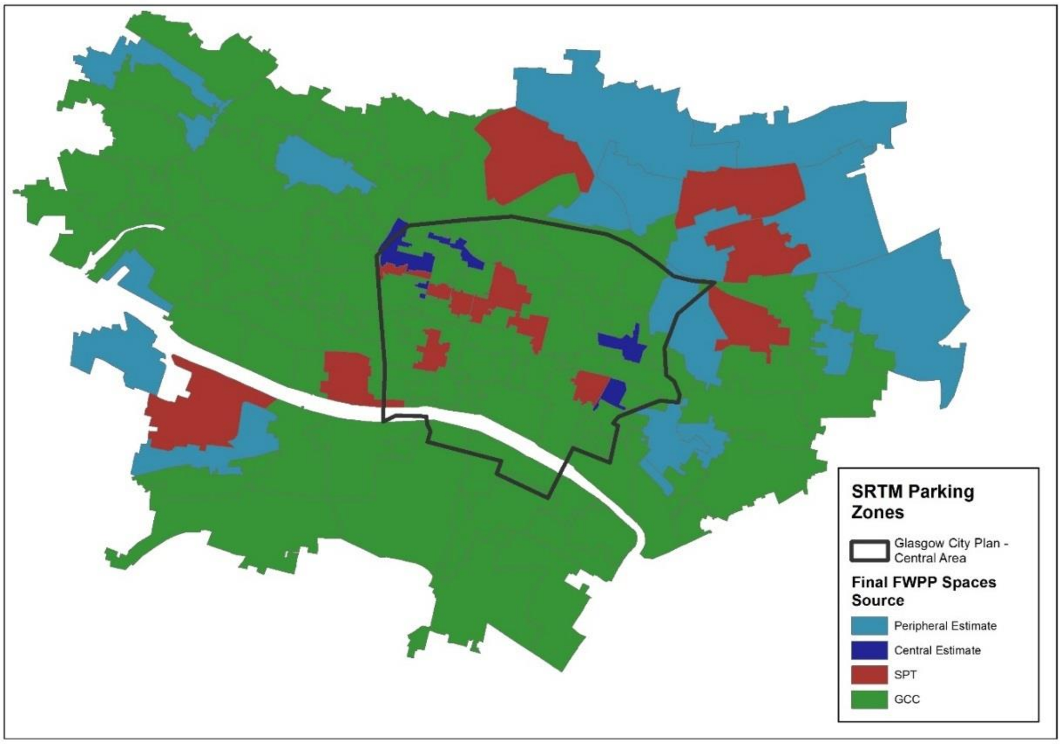


Figure 12. **Free Workplace Parking – Source data**



4.6 Calibration and Validation Approach

4.6.1 With no site specific factors or parameters there is no available mechanism to calibrate this aspect of the model. Similarly, there is no available data on the occupancy levels of free workplace parking.

4.6.2 Consequently, a comparison analysis will be provided during model calibration, the metrics below are currently considered sufficient:

- Free Workplace parking usage (total) by zone;
- Free Workplace parking usage (% of capacity) by zone; and
- Free Workplace Parking as a %age of all parking in zone.

5. PARKING DISTRIBUTION MODEL

5.1 Overview

5.1.1 The parking capacity model has been developed to provide a mechanism to include the average cost and search time of parking in different zones within the demand model.

5.2 Inputs

5.2.1 The inputs of Parking Distribution are the full set of car trips from Mode and Destination Choice and the Free Workplace Parking by tour.

5.2.2 In addition to demand matrices, a csv file is used to detail the number of spaces available at each zone in the model and the parking charges by tour. The derivation of these demand model inputs from the available data is discussed in the following two subsections.

Table 24. Parking Distribution Inputs

COLUMN	VARIABLE	DESCRIPTION	EXAMPLE VALUE
1	Zone	Model zone (numeric)	1
2	Off_Cost	Off street cost per hour – only used to sense check	1.03
3	On_Cost	On street cost per hour – only used to sense check	1.35
4	CapTotal	Smoothed capacity for zone (numeric)	80
5	AM_Search	Search time – from parking model calibration (numeric)	0
6	LT_Search	Search time – from parking model calibration (numeric)	0
7	SR_Search	Search time – from parking model calibration (numeric)	0
8	PM_Search	Search time – from parking model calibration (numeric)	0
9-33	PCharge	Hourly parking charge in pounds for each of the 25 model tours in turn (numeric)	0

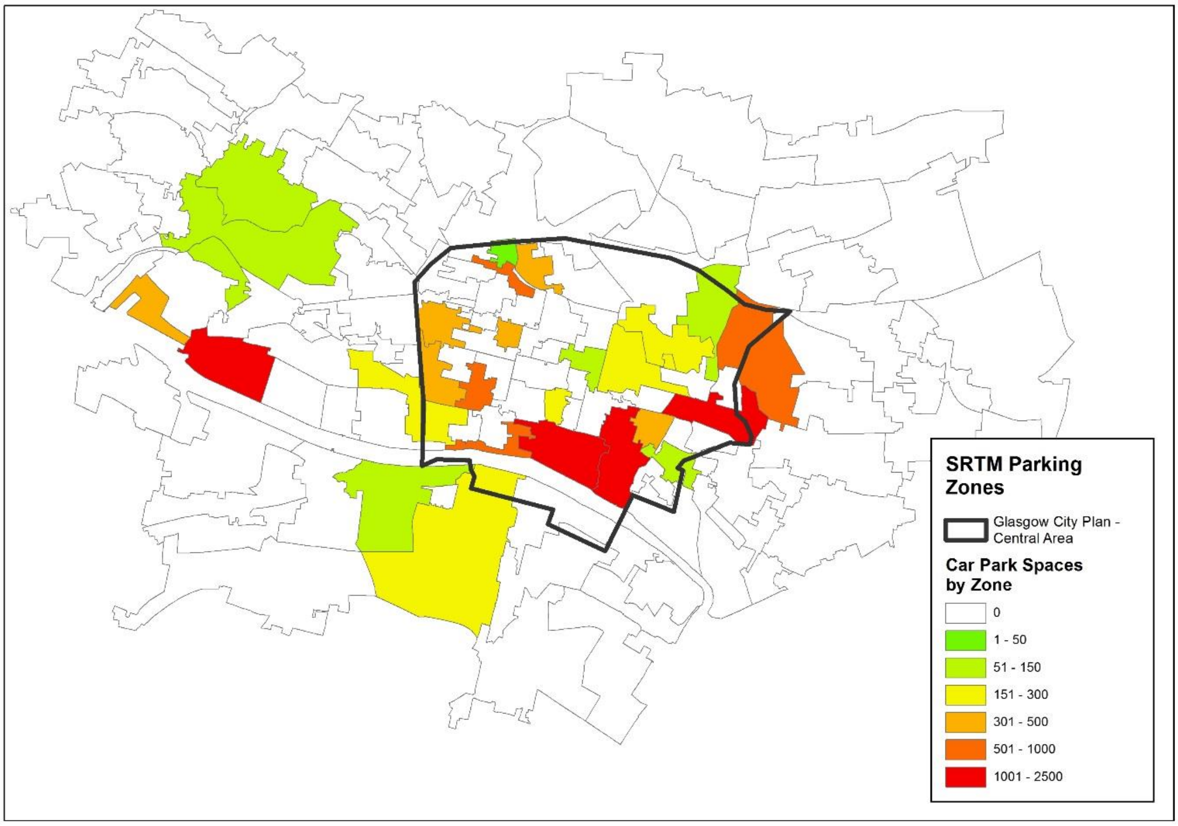
Parking Capacity

5.2.3 The model builds on inputs derived for the parking distribution model that have previously been reported via earlier notes. The relevant sections of that documentation are included for completeness below, with comment mark-up where auditor comments have previously been received.

5.2.4 Information on the capacity of off street parking capacity has been sourced from the Glasgow City Centre Parking Review (AECOM – January 2015). This information has been cross checked against operator websites.

5.2.5 The resulting car park capacities have been aggregated to provide a total of off street car parking by zone, as illustrated in Figure 13.

Figure 13. **Off Street Parking Spaces by Zone**



5.2.6 On-Street parking data has been more difficult to source. While data is available, it does not provide a comprehensive coverage of the SRTM parking area.

5.2.7 The image overleaf illustrates the extent of on-street parking survey data. These data have been aggregated to provide a number of on-street spaces per zone.

5.2.8 For the central area, it has been necessary to estimate the number of spaces. We have applied a ratio sourced from the Glasgow City Car Park Requirement Scoping Study, which stated that on-street parking represented 12% of the central area parking capacity, 42%

was Free Workplace Parking and 46% was off street parking spaces, and that the total of on-street parking within the central area was 2066.

5.2.9 We have taken the free workplace parking numbers and factored by the percentages (12/42) to yield an estimate of on-street parking data by zone.

5.2.10 For the remaining zones with zero on-street parking, an assumption has been made that the zone has the same ratio of on-street parking to free workplace parking as for the central area. The total of estimated on-street by zone is 23,868.

5.2.11 Figure 14 illustrates the surveyed spaces, while Figure 15 shows the infilled parking capacity per zone for on-street parking.

Figure 14. **On Street Parking Spaces by Zone (Surveyed)**

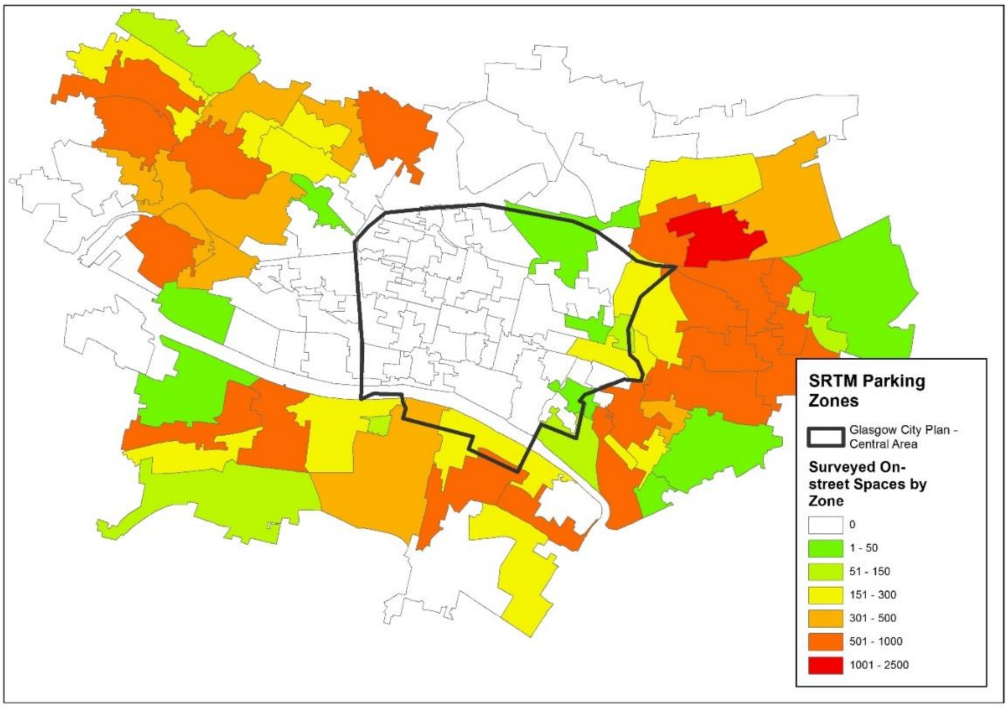
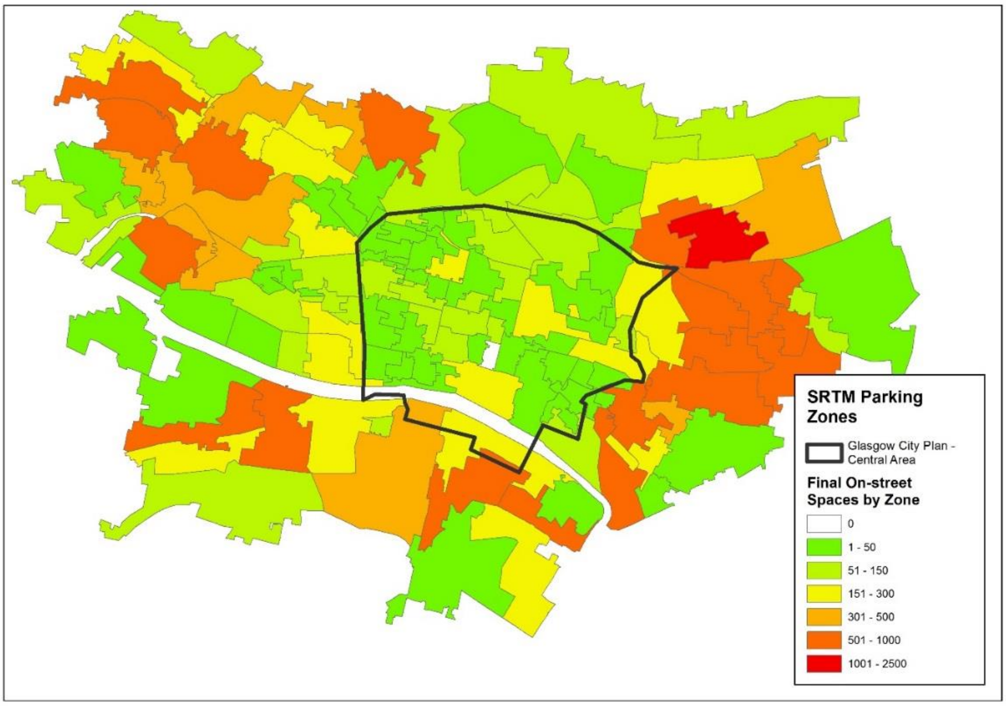


Figure 15. **On Street Parking Spaces by Zone (Infilled)**



Smoothing the Parking Supply

5.2.12 The analysis and infilling process has generated a parking capacity for each specific zone. However, in the absence of a mechanism to allow motorists to park in locations which are not in their true destination zone within the Parking Mode, it is necessary to distribute these spaces across neighbouring zones, particularly to allow the large multi-storey locations to be used by all of the neighbouring zones.

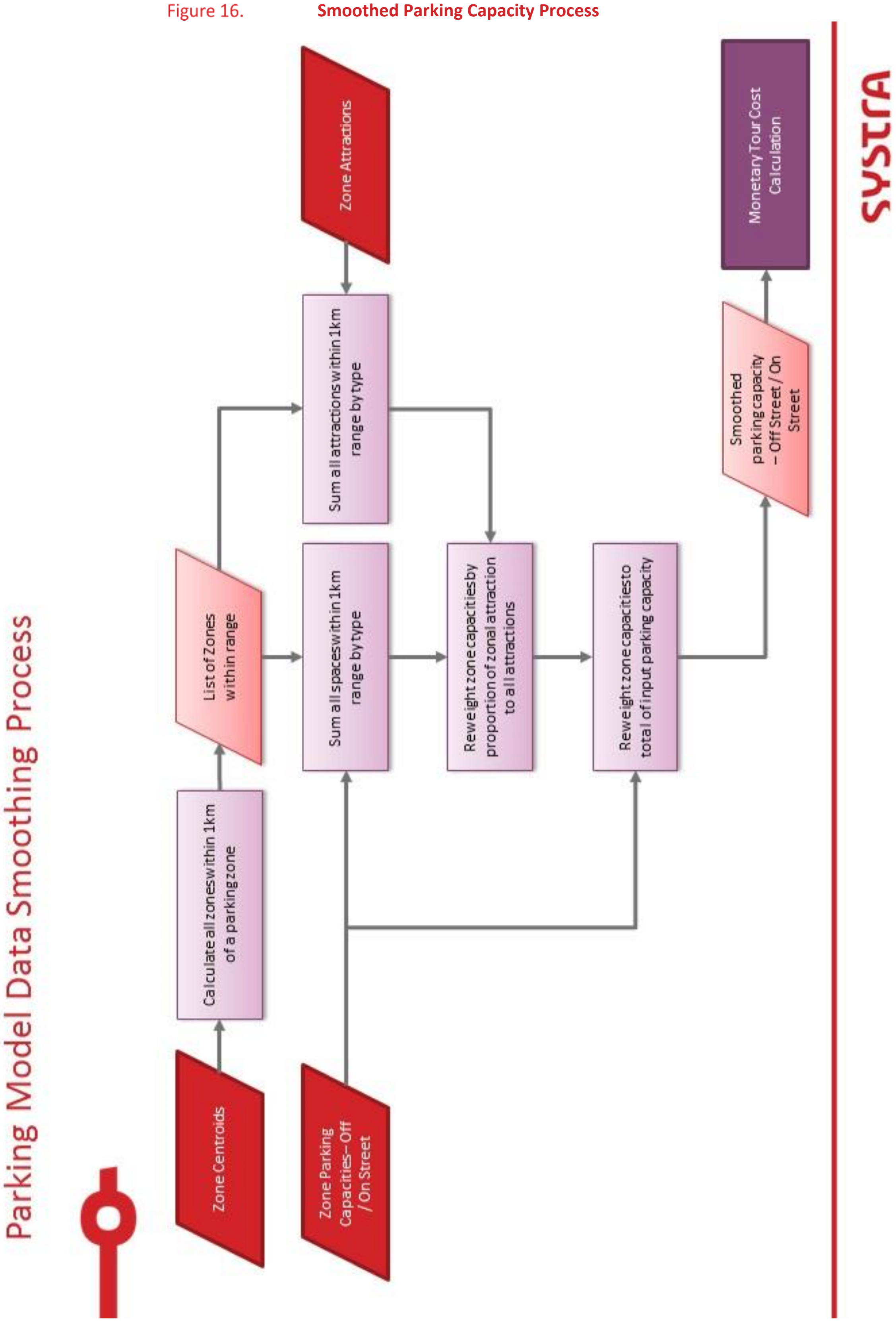
5.2.13 This has been done by aggregating the capacities of nearby zones, and subsequent reweighting to the overall parking total as illustrated in Figure 16 overleaf.

5.2.14 The set of 'nearby' zones included in the smoothing of the parking supply in each zone have been defined using a 1km buffer using crow fly distances between zone centroids.

5.2.15 The smoothing of the paid-for parking supply also uses the trip attractions of the relevant car available trip purposes (i.e. excluding commuting and education), to help distribute the available spaces in a set of neighbouring zones to approximately match the pattern of car-based demand of the relevant trip purposes. The trip attractions used in this process are sourced from the 2014 base year run of the trip end model.

5.2.16 Should no changes be being made to the search times, we would recommend for consistency that the user does not update the attractions to the relevant future year trip ends.

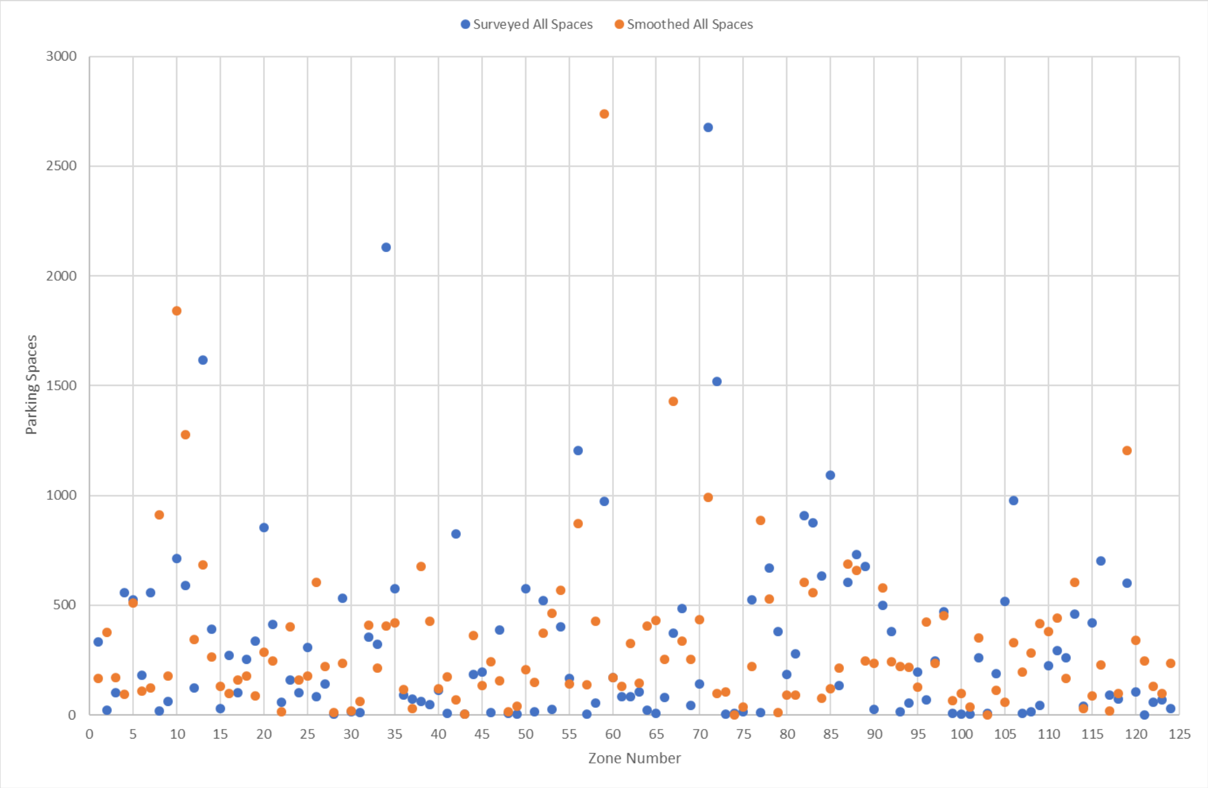
Figure 16. **Smoothed Parking Capacity Process**



5.2.17 The effect of this process is to smooth the parking spaces numbers to reduce the number of zones with single digit capacities and reflect parking locations as drivers perceive.

5.2.18 This can be seen through the following graph, that illustrates the difference between the total spaces by zone as input from the surveyed parking data and those calculated by the smoothing process.

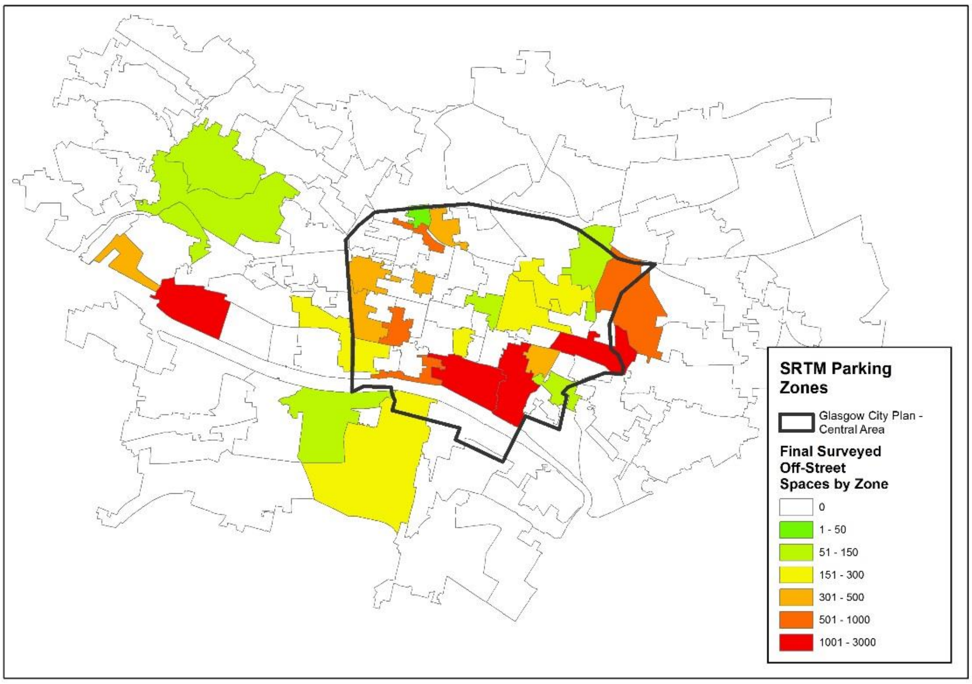
Figure 17. Effect of the Smoothing Process



5.2.19 The following two figures illustrate the effect of the parking capacity smoothing process for off street and on street parking respectively.

Figure 18. **Spatial Effect of the Smoothing Process – Off Street**

SURVEYED



SMOOTHED

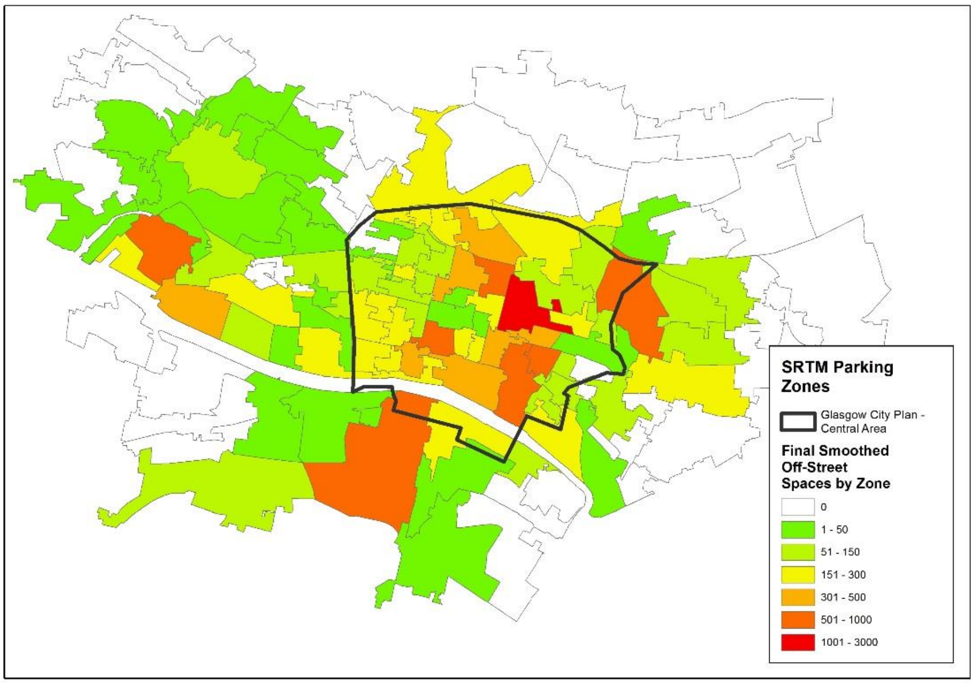
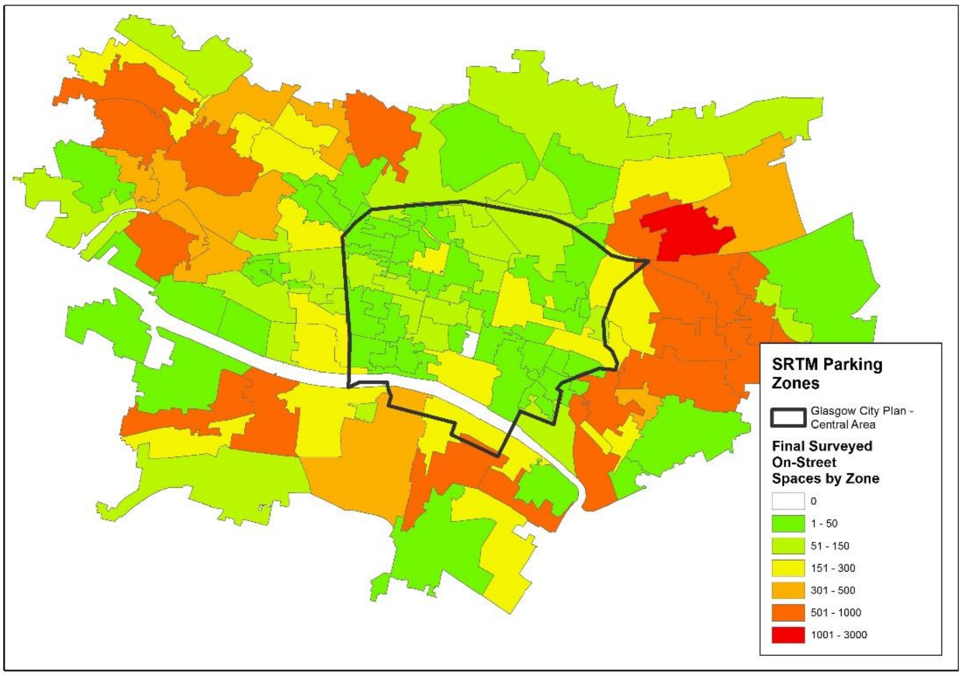
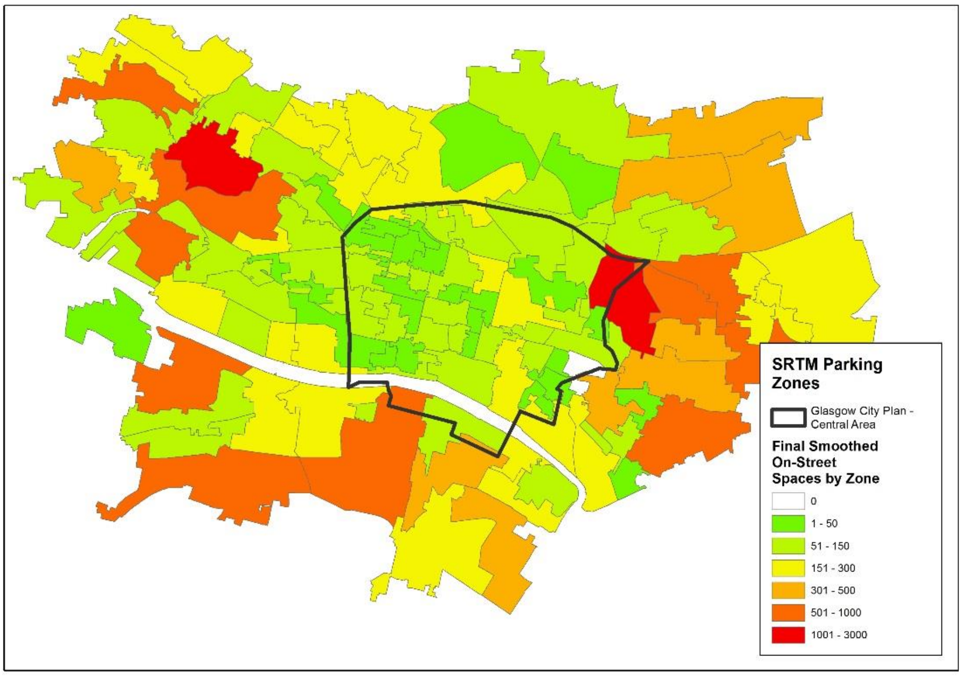


Figure 19. **Spatial Effect of the Smoothing Process – On Street**

SURVEYED



SMOOTHED



5.3 Estimating the Average Parking Charges

5.3.1 Car parking charges for these off-street car parks have been sourced from operator websites, as listed below:

Table 25. Off Street Public Car Parking data

SRTM ZONE	PARKING ZONE CODE	SPACES	OPERATOR	CHARGE £ PER HR
119	CP41	250	Euro Car Parks	£3.30
105	CP20	114	Glasgow Parking	£1.00
113	CP27	124	Glasgow Parking	£1.00
10	CP28	106	Glasgow Parking	£1.20
69	CP21	25	Glasgow Parking	£1.20
33	CP29	82	Glasgow Parking	£0.80
60	CP22A	65	Glasgow Parking	£1.20
60	CP22B	89	Glasgow Parking	£1.20
61	CP22D	82	Glasgow Parking	£1.20
72	CP26	98	Glasgow Parking	£1.40
34	CP24	112	Glasgow Parking	£1.40
32	CP1	325	Glasgow Parking	£1.80
71	CP4	598	Glasgow Parking	£2.00
29	CP3	433	Glasgow Parking	£1.80
42	CP2	812	Glasgow Parking	£2.00
72	CP5	1170	Glasgow Parking	£1.40
68	CP6	460	Glasgow Parking	£1.20
14	CP61	360	Glasgow Parking	£1.00
13	CP62	1600	Glasgow Parking	£4.00

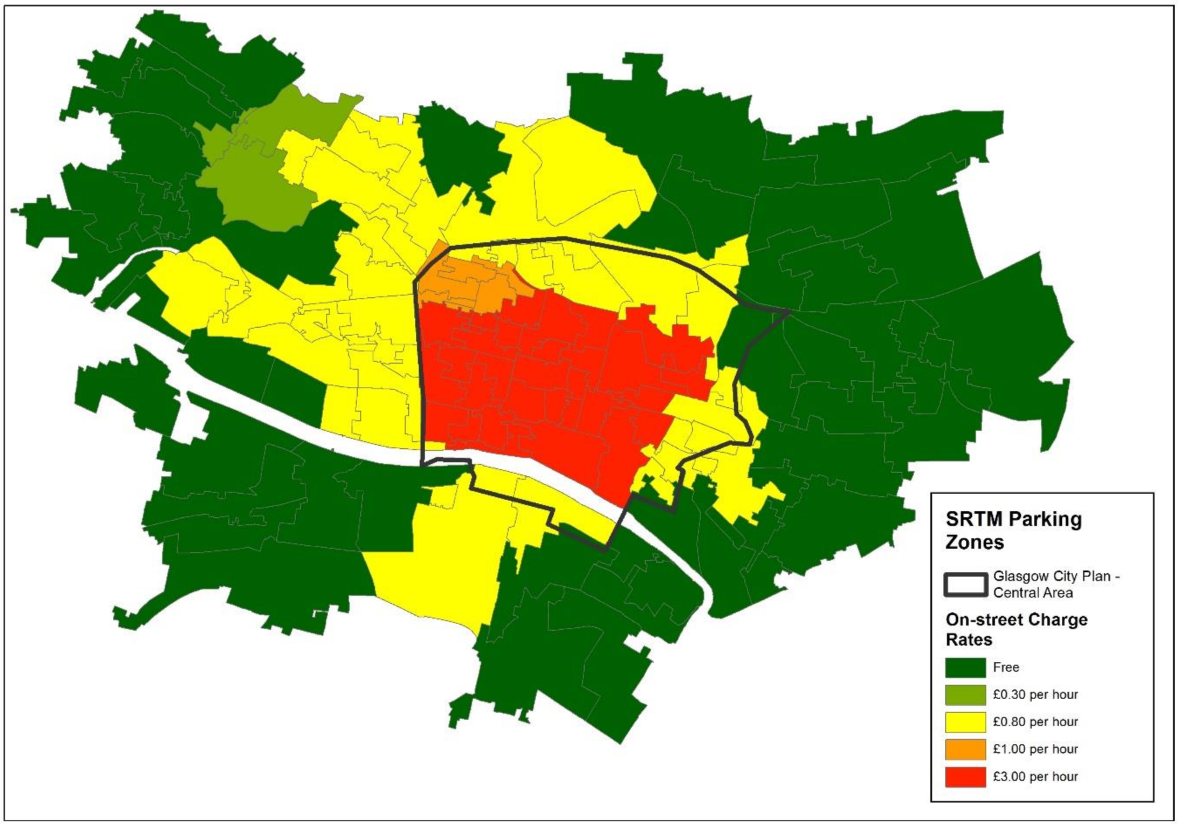
SRTM ZONE	PARKING ZONE CODE	SPACES	OPERATOR	CHARGE £ PER HR
59	CP12	706	http://www.apcoa.co.uk/parking-in/glasgow/glasgow-royal-infirmary.html	£1.60
71	CP13	2000	http://www.buchanangalleries.co.uk/getting-here	£1.50
115	CP43 A	220	http://www.rcpparking.com/car_parks/park/20#search=&park=20	£0.90
33	CP45	200	http://www.smartparking.com/contact	£1.50
34	CP14	900	http://www.st-enoch.com/parking/	£1.50
66	CP47	76	National Rail	£3.50
54	CP36	35	NCP	£6.00
56	CP25	620	NCP	£2.50
67	CP16	202	NCP	£3.50
44	CP17	184	NCP	£3.50
56	CP18	545	NCP	£3.50
35	CP19	555	NCP	£3.50
54	CP7	365	Q-Park	£2.00
34	CP8	560	Q-Park	£1.50
47	CP9	372	Q-Park	£2.00
116	CP11	660	Q-Park	£2.60
34	CP10	360	Q-Park	£1.50
55	CP31	113	Glasgow Cross	£1.20
55	CP32	32		£1.20
25	CP51	49		£0.00
25	CP49	41		£0.00

5.3.2 Information from Glasgow City Council on-street parking website https://www.glasgow.gov.uk/) were used to inform the estimation of on-street parking charges for different durations of tour.

5.3.3 It should be noted that the parking charges was converted to a model price base consistent with other monetary values (generalised minutes) in the using parking value of time.

5.3.4 The average cost per hour assumed for on-street parking by location is illustrated in the figure below.

Figure 20. **On Street Parking Charges by Zone**



5.3.5 These hourly charge by car parking type have been combined to produce a single car parking charge (in £) by tour.

5.3.6 The following have been taken into account when approximating the average parking charge in each parking zone:

- The price of parking should reflect the duration of the tour;
- The price of the parking which goes into the model is the 'per vehicle' charge, (so will need to be divided by vehicle occupancy of the relevant demand segment when estimating the generalised costs for person-trips;
- The average cost per hour of on-street and off-street parking may differ by the duration and will therefore differ for different tours;

- The average cost per hour of parking will therefore vary between zones, based on the mix of off-street and on-street spaces used and the mix of tours in the relevant pattern of travel demand;
- Run-time considerations preclude the inclusion of a parking location choice model (e.g. as an additional inner loop within the demand model), so the aim is to estimate and use approximate average costs in each zone, without knowing the precise split of off-street and on-street used in each zone in a given future year;
- Increasing the cost of one of the types of parking (off-street and on-street) should increase the average cost, but be pro rata to the likely mix of the two types of spaces being used in that zone; and
- In particular, the price of parking in zones with no off-street spaces should be based on the on-street charges (and vice versa);

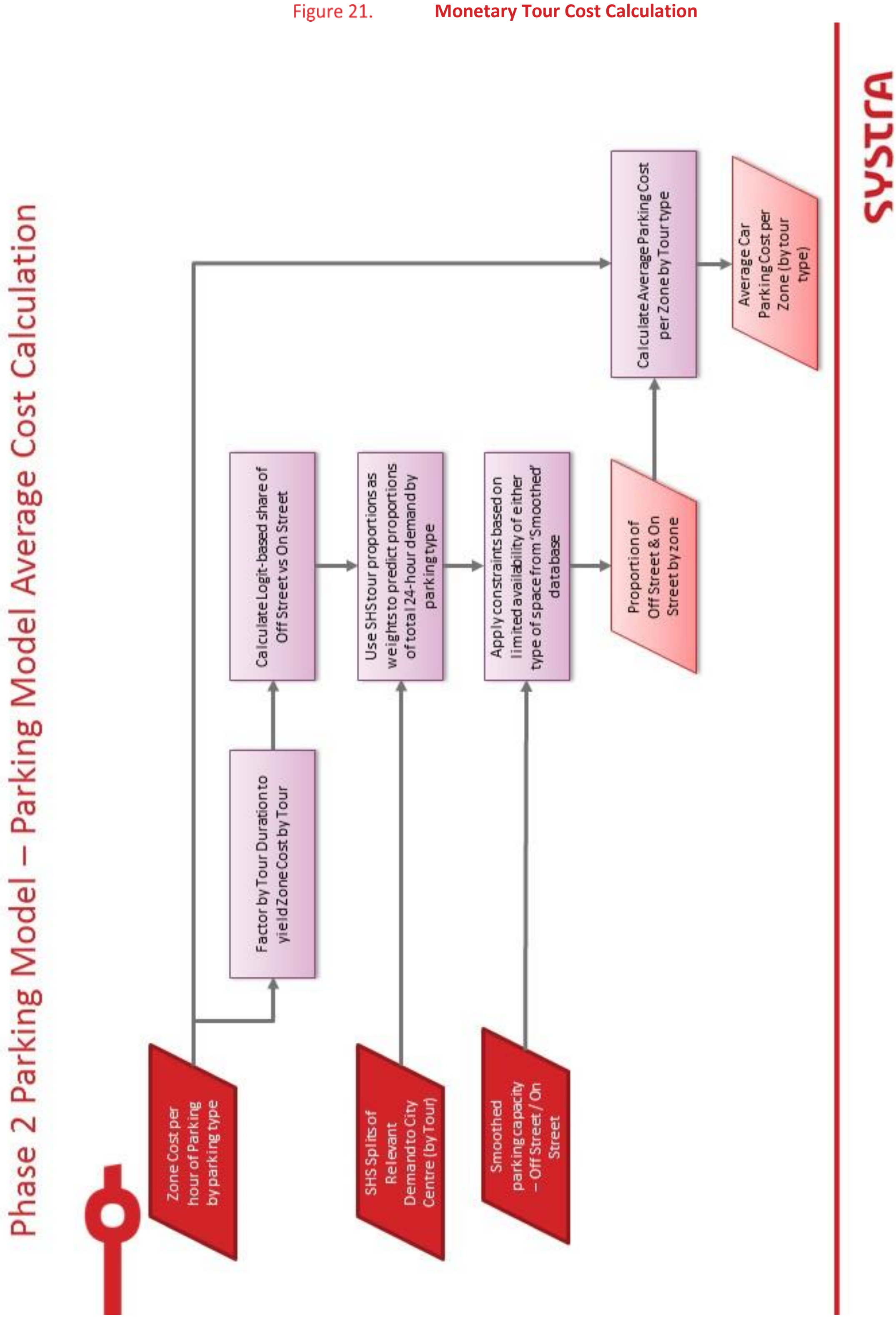
5.3.7 The basic inputs to the calculation of the average cost are:

- the average costs of off-street and on-street parking for each tour type parking in the parking zone;
- the profile of the 24-hr base-year demand by tour type, based on the relevant demand segments (i.e. car available and excluding commuting and education) – this is used to estimate the likely split between off-street and on-street within the cost calculation; and
- any user-defined capacity constraints on the 24-hour parking patterns in specific zones (i.e. where the target split between off-street and on-street based purely on the relative costs cannot be achieved).

5.3.8 The key steps of this calculation for an individual zone are as follows:

- The use of a logit-based model to represent the unconstrained cost between off-street and on-street for a given tour parking in the chosen zone;
- Use the profile of tour proportions for car-based travel to the city centre for the relevant purposes to estimate the corresponding split of the total 24-travel travel demand between on and off-street parking in this zone;
- The application of capacity constraints (if necessary), to adjust the 24-hour pattern to lie within the user-defined limits on the two proportions for this zone – for example to ensure a 100% on-street share in zones with no off-street parking spaces; and
- The calculation of the resulting average cost of parking (per vehicle) in this zone for each of the 25 tour types.

Figure 21. **Monetary Tour Cost Calculation**



5.4 Outputs

5.4.1 The parking model outputs a file documenting the zone, the parking numbers and percentage occupancy of zone by time period.

5.4.2 The convergence process in the model includes a convergence report for trips destined to the zones that comprise the parking model area for further analysis.

5.5 Calculation Steps

5.5.1 The model has been specified to run in two different modes, calibration mode and model operation mode. This is to minimise the run times of the overall SRTM by utilising converged base year parking search time costs as a proxy for the model calculating these times dynamically.

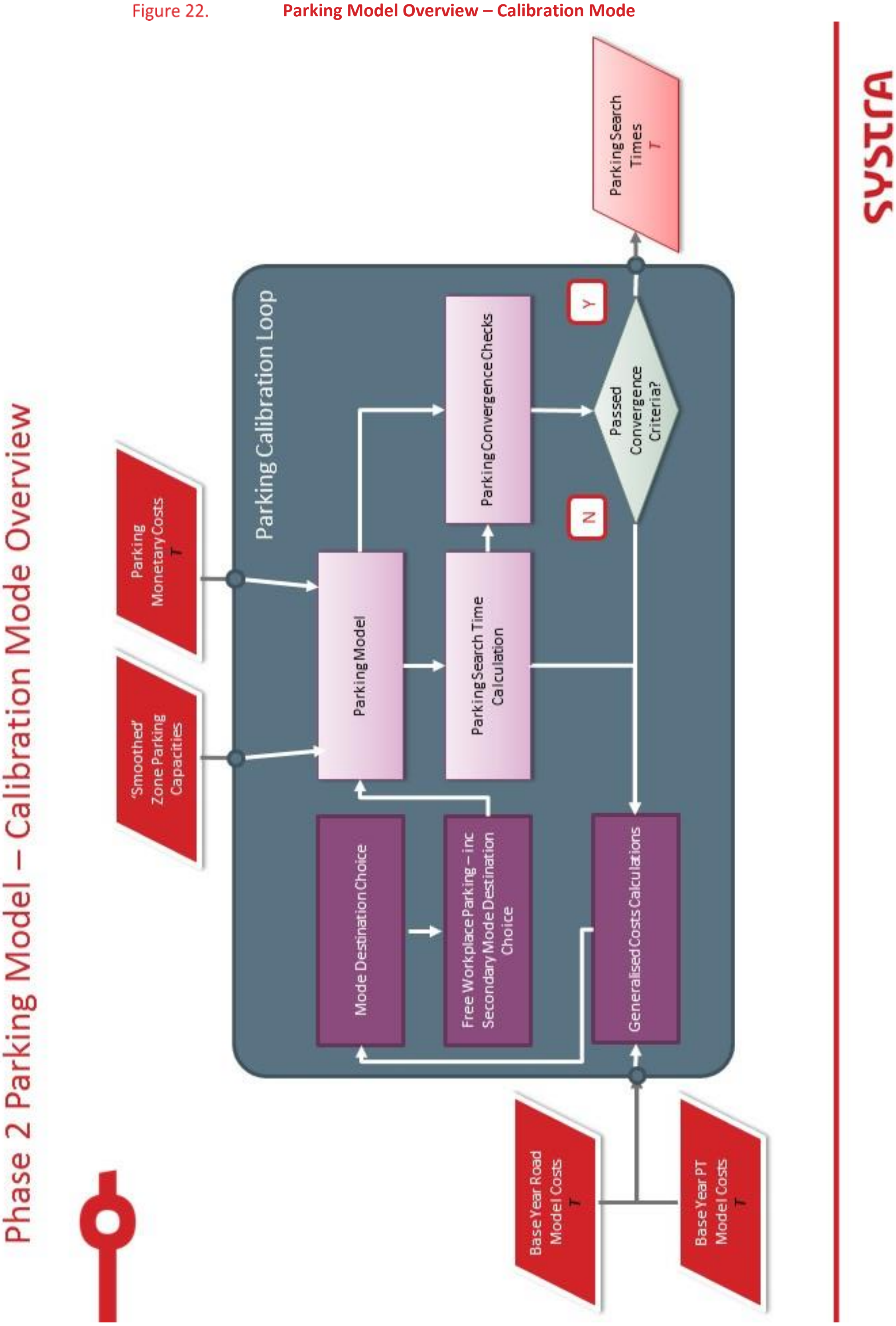
5.5.2 The parking model calibration mode estimates parking search times through iteration of the demand model until the model replicates observed mode shares for the parking model area.

5.5.3 The parking model operation mode uses these calibrated costs as search times on each loop within the overall demand model. In this way, parking search times are included in model forecasts.

5.5.4 While this is a simplification, the model will produce a report illustrating the vehicle occupancy of each parking zone at the end of each time period. The user is recommended to view this file, and should the occupancy be greater than 120% re-run the parking cost calibration mode to estimate revised parking search times.

5.5.5 The calibration mode process is illustrated below in Figure 22.

Figure 22. **Parking Model Overview – Calibration Mode**



5.5.6 The process makes use of two components, the parking model and the parking search time calculation component. These components are illustrated in the following two figures.

5.5.7 The parking model component starts by converting the road person trip matrices by demand segment to vehicle trips using the SHS derived car occupancy factors.

5.5.8 Following this, the model loops through the five time periods and calculates the parking totals by zone at the end of each time period. From this, the remaining zonal parking capacity is calculated, together with the time period occupancy percentage.

5.5.9 The component ends by collecting the car park usages and reports for user inspection.

5.5.10 This is shown diagrammatically in Figure 23.

5.5.11 The parking search time component takes these occupancies and calculates a parking search time cost based on a curve of the following form:

$$Search\,Time = Min\left(\frac{MinTime}{(\%\,Spare)^{C}}, MaxTime\right)$$

$$\%\,Spare = Max\left(1 - \frac{Dem_z}{Cap_z}, 0.001\right)$$

Where: Min_Time and Max_Time are the assumed minimum and maximum search times, set to 10 minutes and 240 minutes for our example curve

%Spare is the unused parking capacity in the given time period (capped to be >= 0.1%)

C is a calibration power value, assumed to be 1 in our example

Z is the zone

Cap is the smoothed capacity of the zone (combining off-street and on-street) for the AM period, for subsequent periods the capacity is the capacity remaining from the previous time period, plus the vehicles that leave during the current time period

Dem is the current parking demand in the zone

5.5.12 MinTime, MaxTime and C are calibration parameters which will be chosen to ensure that the overall car mode share of the relevant trip purposes to the controlled parking area broadly matches the expected values and few, if any of the individual zones exceed their (smoothed) parking capacity in any time period.

5.5.13 The use of the 1/(Spare Capacity)^c term is used to ensure that the search time rises rapidly as the number of spare spaces falls towards zero, (to ensure that the demand for parking will generally converge to a value lower than the capacity), while avoiding the convergence problems associated with adopting a hard-wired capping approach.

5.5.14 An example of the curve, based on the assumed values above is included within Figure 24 that provides a process diagram of the search time calculation approach.

5.5.15 This results in a current parking search time by zone, which is then passed to the generalised cost calculation for the subsequent loop, and to the process that calculates convergence.

5.5.16 When in calibration mode, the process will iterate around the demand model, including the above two components until convergence is reached, with the parking search time curve calibrated – in tandem with the overall demand model – to the observed mode shares from SHS data / census journey to work.

5.5.17 The operation mode of the parking model is illustrated below in Figure 25.

5.5.18 The parking model referenced in the figure is as shown in Figure 23, with parking search times as established from the calibration mode.

Figure 23. **Parking Model Component**

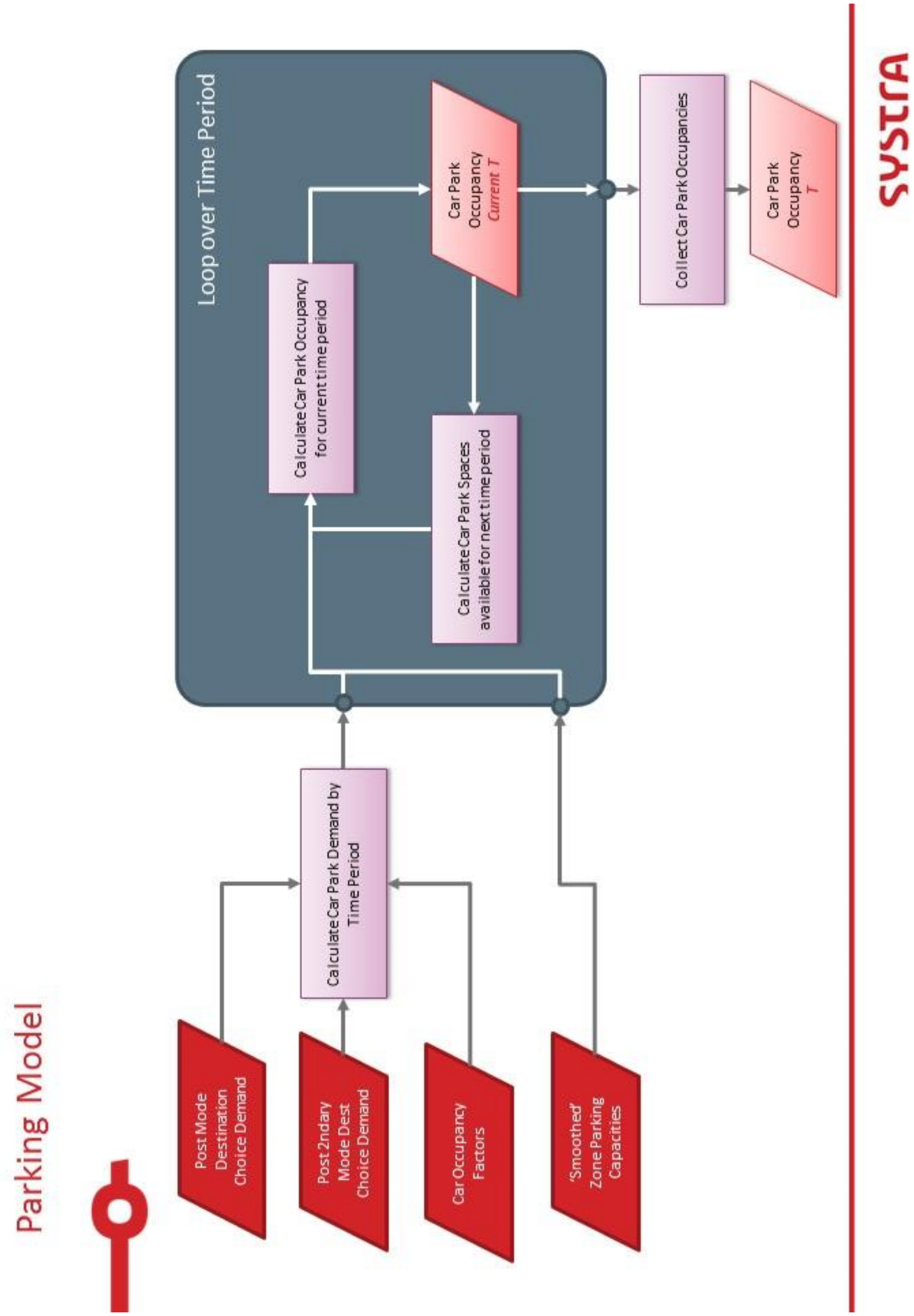


Figure 24. **Parking Search Time Calculation Component**

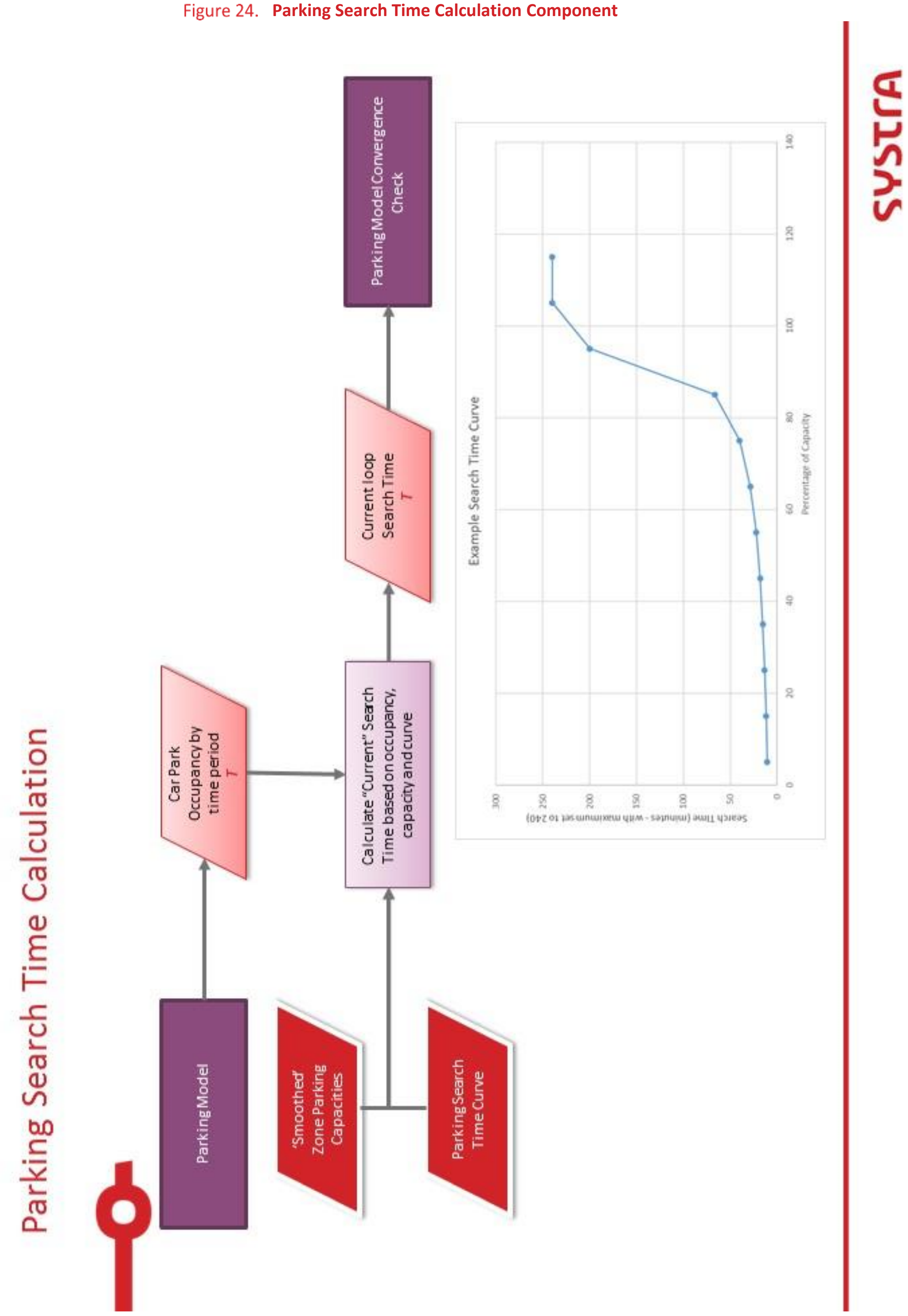
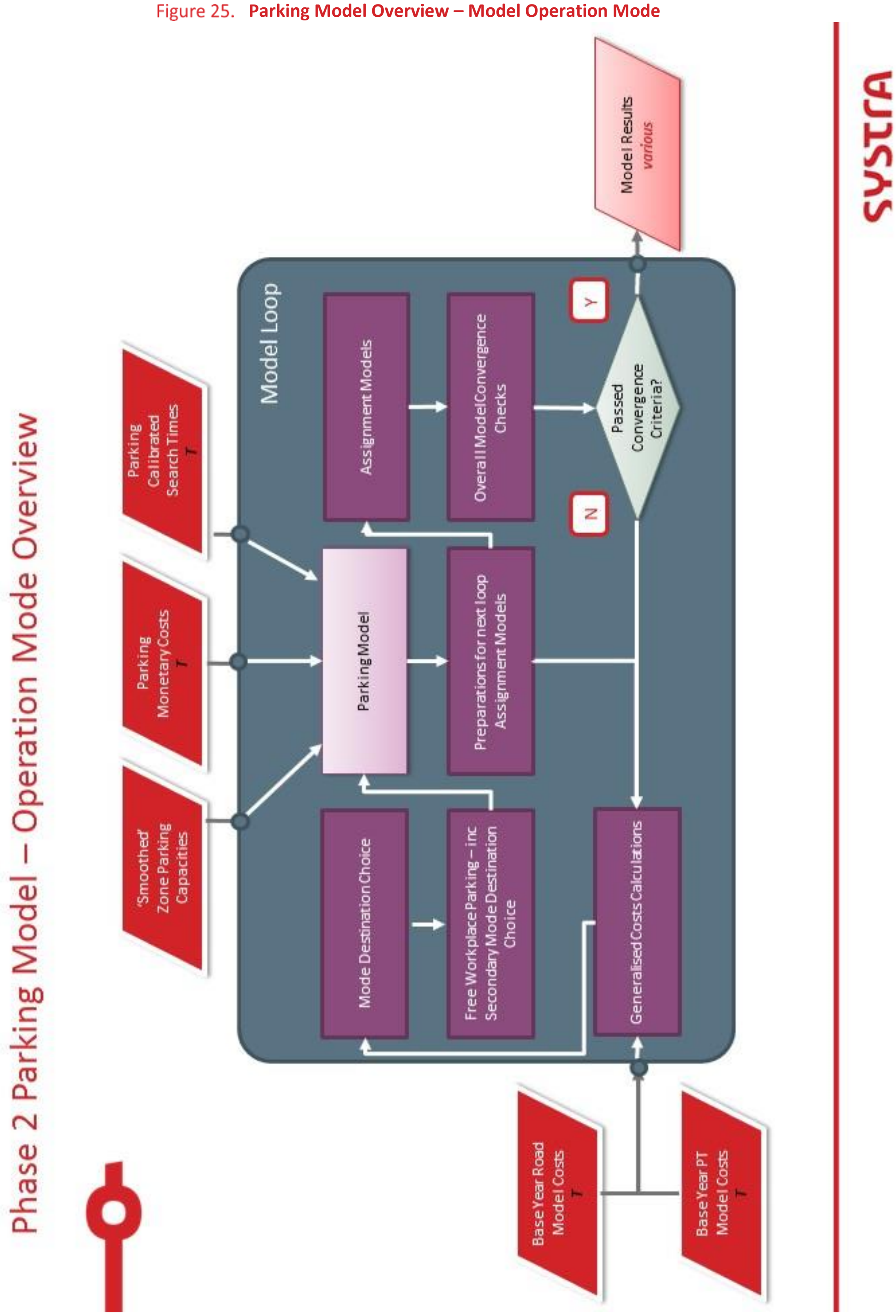


Figure 25. **Parking Model Overview – Model Operation Mode**



5.6 Calibration and Validation Approach

5.6.1 The parking component will be calibrated as part of the overall calibration of the demand model.

5.6.2 The overall model will be calibrated to observed mode split by demand segment to the parking area as sourced from Census and SHS data for commute and other demand segments respectively.

5.6.3 The lack of occupancy data restricts the ability to formally calibrate and validate the model in line with WebTAG guidance.

5.6.4 Consequently, we propose to undertake a comparison of outputs from the parking model, the metrics below are currently considered sufficient:

- Comparison of modelled usage, presented in GIS; and
- Displays of percentage occupancy at each site throughout the day and comparison against the observed equivalent.

6. PARK AND RIDE MODEL

6.1 Specification of Park and Ride

6.1.1 The PnR model is a logit-based choice mechanism which evaluates the choice of parking location for Park and Ride following the mode choice model determining park and ride as the chosen mode. Kiss and Ride is omitted from this model as the measure of Park and Ride usage is the number of vehicles which occupy a space and Kiss and Ride travellers do not contribute to these.

6.1.2 It takes into account the travel costs to and from each site by the relevant mode, the duration of the stay, the associated parking charges, and the number of available spaces.

6.1.3 Park and Ride within the SRTM is considered as a trip which transfers between road and PT (in that order for the outbound trip) on a single trip and returns using the same set of modes in reverse. This is illustrated in the figure below.

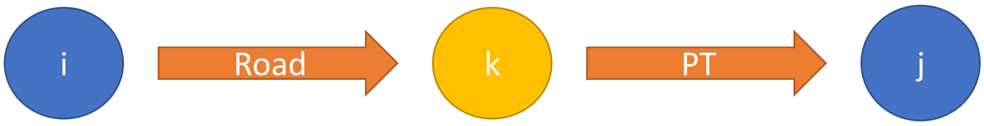


Figure 26. **Breakdown of Park and Ride**

Where:

i is the true origin

j is the true destination; and

k is the intermediate park and ride zone.

6.1.4 Further, the interchange is only considered at specific zones which offer formal Park and Ride or station parking services described in the 'Site File' explained in the following sections.

6.1.5 This report aims to outline the processing done to date in order to construct this module into the overall demand model. Further, information including the mathematical framework used can be found in the SRTM Specification Report.

6.2 Data Sources

6.2.1 The data used in the construction of the SRTM PnR model was:

- Scottish Household Survey data – as supplied from Transport Scotland;
- 2011 Census Data Zones boundary files;
- 2001 Census Data Zones boundary files;
- SRTM zone system;
- National Rail Travel Survey (NRTS);
- Central Scotland Transport Model (CSTM) Park and Ride Data; and
- SPT Survey Data.

6.3 Inputs

6.3.1 The modelled inputs to Park and Ride comes from the mode and destination model for the majority of user classes and the FWPP mode for commuters. It consists of individual files by user class with 25 tours for each purpose considered in each file. It should be noted that one-way trips are excluded from using Park and Ride as a choice and therefore do not appear in this component of the model.

6.3.2 Initially a 'site file' was created which defines the attributes for each Park and Ride site. This site is in a CSV format (delimited by single quotes), which makes it easy for the user to adjust. The table below provides details on the variables that can be found in a site file.

Table 26. Park and Ride Site File Description

COLUMN	VARIABLE	DESCRIPTION
1	ID	Sequential numeric identifier
2	Name	Site name, used in reporting (character)
3	Zone	Corresponding model zone (numeric)
4	Parking Charge	Parking charge in £s (numeric)
5-9	Bttr	Base penalty by time period (numeric)
10-14	Attr	Attraction factor by time period (numeric)
15	Near capacity	Formal capacity at site (numeric)
16	Far capacity	Limit to informal and formal capacity at site (numeric)
17	Origin Catchment	List of origin zone within reasonable distance of this particular site (character)
18	Destination Catchment	List of destination zones within reasonable distance of this particular site (character)

6.3.3 There were in total 194 Park and Ride sites chosen which was in the modelled area. These consisted of all the rail stations in the internal modelled area, 3 subway and 3 bus stations. The full list can be seen in Appendix C.

6.3.4 The zone for each site were obtained from the STRM zone system, allocating to the nearest zone a rail station fall in.

6.3.5 The parking charge for each site where possible was obtained from the CSTM12 model.

6.3.6 The near capacity of each site was obtained through several sources as found in section 1.3.1. Where possible the capacity was obtained from SPT[4] was used. For stations where this was not available, the CSTM12 PnR data was used. The capacities for each site is shown in Appendix C.

6.3.7 The origin catchment was initial derived from the data extracted from the NRTS. This provided a guide as to where the origins catchment might be for a site. It was based on the records identified as 'car parked at or near station' and 'car- passenger dropped off'. Due to the lack of records the latter was used as this was only to evaluate the general pattern of trips and typically the patterns for these are the same. The catchment was then evaluated and extended to provide a more realistic catchment area.

6.3.8 The Park and Ride model enables the destination catchment to be the extent of model. While initially it seems extreme to leave destination catchments open, the mode choice mechanism applied later limits the longer distance trips.

6.4 Occupancy

6.4.1 The occupancy levels for each site was derived from an array of different sources. The data availability for the occupancy levels were limited from the SPT survey data. Where information was lacking, the historic CSTM model uses data from a variety of different sources for example, ScotRail Car Park Counts (2013), ScotRail Car Park Audit (2012), SPT Surveys - Number of questionnaires (2011/2012), Subway Park Token Returns (2013) among others all pre 2013.

6.4.2 The full list of occupancy levels used as part of the initial demand model input is shown and their levels can be seen in Appendix C.

6.4.3 It is assumed that where not explicitly stated, the occupancy levels are for the Lunch Time (LT) time period.

6.4.4 The tour occupancy will be used to calculate the magnitudes by tour by evaluating the percentage of total capacity being utilised aligned with tour proportions from the SHS described in 6.7.1.

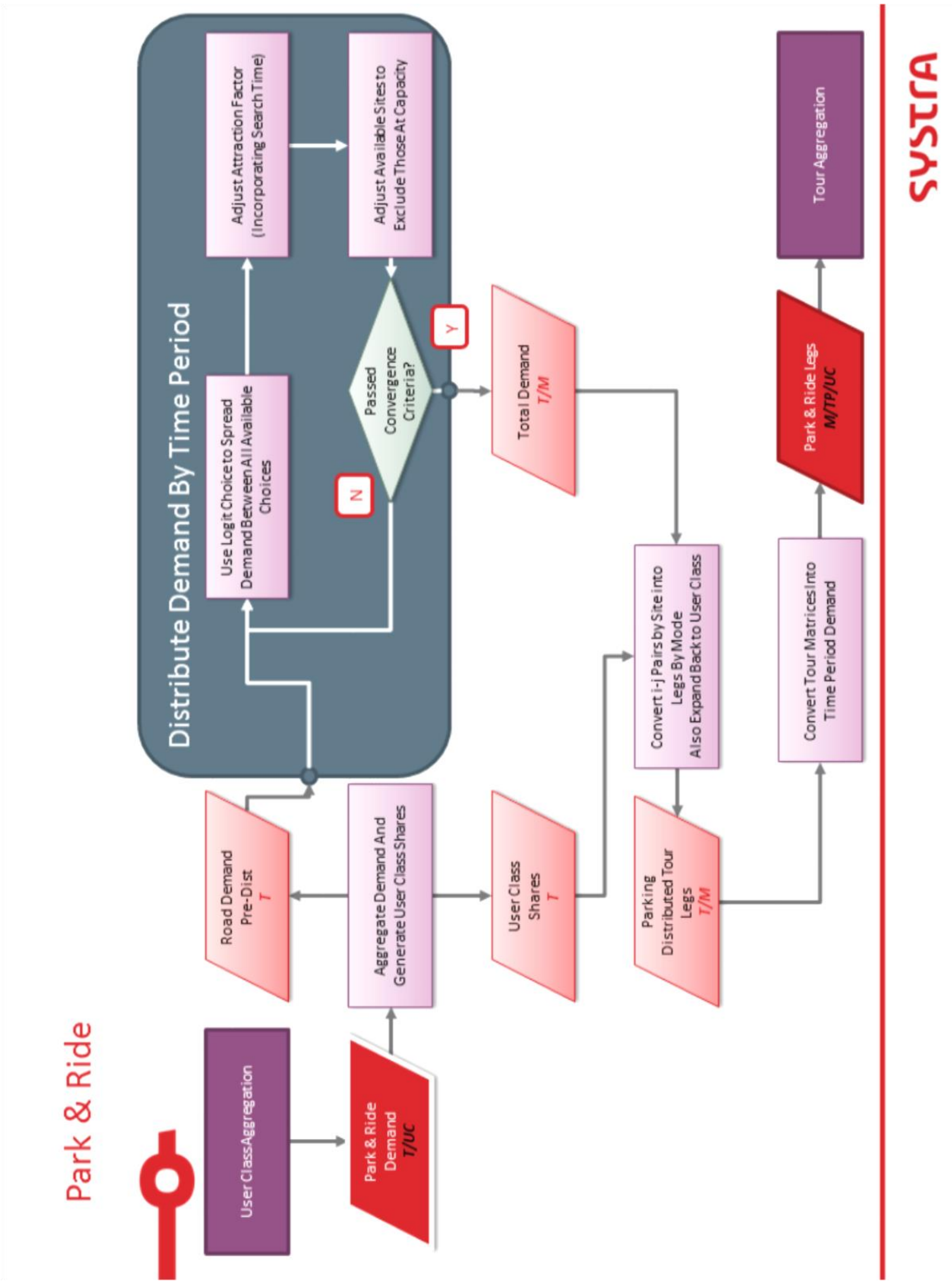
6.5 Outputs

6.5.1 The outputs of the Park and Ride model are matrix files detailing trip movements by user class (5), time period (5), direction (2, From Home and To Home), and mode (2, road and PT).

6.5.2 As well as the trip movements, the impact of Park and Ride is reported via text files where it is possible for model users to quickly establish the usage at each site by tour (and hence time period).

[4] http://www.spt.co.uk/park-ride/

Figure 27. **Park and Ride Model Processes**



6.6 Mathematical Framework

Site Choice

6.6.1 Park and Ride is modelled using a standard logit approach based on the sites available to make a true origin destination trip. The logit choice will be calculated as:

$$P_{ijs} = \frac{e^{\lambda U_{ijs}}}{\sum_{s \in S} e^{\lambda U_{ijs}}}$$

Where:

P_s is the probability of choosing site s;
$\lambda < 0$ is the spread parameter for Park & Ride site choice;
S represents the choice set of available sites (as defined by catchments); and
U_{ijs} is the utility of travelling from zone i to zone j via site s.

6.6.2 The utility here can be further expanded into its relevant components:

$$U_s = \frac{(GCar_{ikT1} + GWK_{kjT1} + GWK_{jkT2} + GCar_{kiT2})}{2} + P + Attr$$

Where:

$GCar_{ikT1}$ is the generalised cost of travelling by car from zone i to zone k during time period 1;
GWK_{kjT1} is the generalised cost of travelling by walking from zone k to zone j during time period 1;
GWK_{jkT2} is the generalised cost of travelling by walking from zone j to zone k during time period 2;
$GCar_{kiT2}$ is the generalised cost of travelling by car from zone k to zone i during time period 2;
P is the parking charge per person for a site (in generalised minutes); and
$Attr$ is the attraction factor at a site which includes the “search” cost at the site introduced by the Park & Ride constraint function.

6.6.3 The first four values is available directly from the generalised cost matrices while P and $Attr$ will be defined in the defined input site file. Note that on subsequent loops the value of $Attr$ will be adjusted by the capacity constraint mechanism.

6.6.4 As the model strictly works in generalised minutes as a unit when considering generalised cost, some of the values above must be converted first to be consistent, specifically parking charges which are converted from euros per vehicle into minutes per person using the approach

$$P_{Person} = 60 * \frac{P_{Vehicle}}{2} * \frac{Occ}{VoT}$$

Where:

P_{Person} is the perceived parking charge each vehicle occupant pays in generalised minutes;

$P_{Vehicle}$ is the daily parking charge in euros;

Occ is the occupancy of each car, considered here to be 1.44 as a general parameter and not consistent with the CDCU factors used elsewhere in the model (defined by catalog key);

VoT is the value of time, taken as commute as a standard assumption (value of 12.91 in the base year) and defined via catalog key.

Capacity Constraint

6.6.5 Capacity constraint is implemented by applying a penalty as part of the site choice mechanism and there are two approaches which are used. The first approach is to use a "stepped" approach where costs remain the same up to a threshold and then increase for all other users while the second is to use an exponential cost increase.

6.6.6 To implement the first, a penalty is calculated as:

$$Attr = Bp + \frac{g(D_s - C_s)^2}{\max(1, D_s)}$$

Where:

$Attr$ is the capacity constraint penalty;
Bp is the base penalty, a calibrated parameter which allows sites to be over capacity in the base year should observed data indicate;
g is the gradient of the response, defined in calibration;
D_s is the site demand on the current iteration; and
C_s is the site capacity.

6.6.7 The second is implemented by introducing a far capacity penalty which provides a sharp increase in utility to move passengers away from a particular site. Note that where a far capacity has been coded as zero it is assumed that there is unlimited informal parking and this mechanism is not applied.

6.7 Initial Usage Estimate

6.7.1 For the data sources available, the demand was only observed for one time period, thus the site usage for a given site was calculated based on a set of tour proportions. This pattern was obtained from the Scottish Household Survey (SHS) by evaluating the car trips made by tour. The table below depicts the tour matrix used.

Table 27. SHS Observed Tour Matrix

	1	2	3	4	5
1	3.4%	4.2%	6.1%	25.1%	2.7%
2	0.0%	7.4%	6.1%	3.5%	1.1%
3	0.0%	0.0%	7.9%	4.9%	1.9%
4	0.0%	0.0%	0.0%	5.1%	7.0%
5	0.2%	0.4%	2.3%	4.4%	6.3%

6.7.2 The observed tour proportion was established by considering the car (driver) trips only regardless of the purpose.

6.7.3 Upon establishing the occupancy levels for each time period and overall demand by time period is established for each site. This is further disaggregated by tours using the same matrix as shown above. It is assumed that the occupancy levels are zero for the off peak time period (overnight stay is negligible).

6.8 Generating Synthetic Demand Derivation

6.8.1 In order to calibrate the model, either a robust set of observed data or synthetic demand is required. These data provide patterns for trips for each park and ride site.

6.8.2 The observed data for a given origin to destination pair via a station was extracted from the NRTS. However, due to the lack of data, this was not possible for all the Park and Ride stations. Where observed data was not available, synthetic demand of travel patterns between origins and destinations via park and ride site was created through a gravity based approach using costs from the latest network.

6.8.3 The process that been set up for all the stations in the internal modelled area. The output for those sites with observed data will be used as a comparator check against the 'true' observed data. Based on the available data we have identified the number of unique origin zones for each site (listed in Appendix C), for those sites where the number of unique origin zones is lower than or equal to 5 we are proposing to use the synthetic demand.

6.8.4 A Voyager application was created which goes through a series of steps shown below.

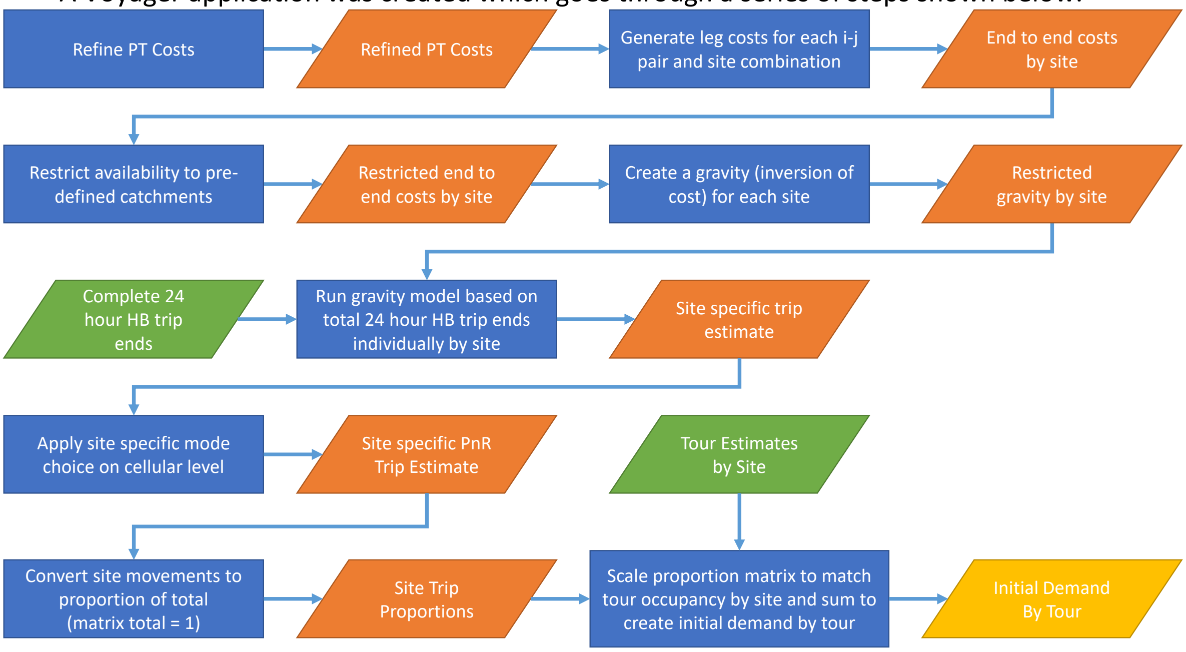


Figure 28. **Initial Demand Synthesised Derivation**

6.8.5 The initial step of refining the PT costs was established to remove potential walk access to the park and ride site as they are not regarded as PnR trips. The PT costs were cleaned by replacing any costs based on walking (where boardings were zero) with an arbitrary high cost.

6.8.6 The origin and destination catchments used in this process, were from the same site file described in the preceding section.

6.8.7 A gravity model is then run based on total 24 hour home-based demand using an inverted cost with zone-pairs outside the catchments excluded. This provides an initial site usage which then has mode choice applied to it (using a lambda value of -0.15) to allow each zone pair to choose between modes.

6.8.8 This Park and Ride demand is then scaled down to represent a proportion of itself such that the matrix total equals one, which can then be scaled up to reflect tour estimate (individually by site) and subsequently summed to create an overall initial Park and Ride demand. This approach has the advantage that the modelled usage will match overall levels of demand exactly and that approximately reasonable levels of demand will travel between zone pairs.

6.9 Calibration and Validation Approach

6.9.1 As mentioned in the previous sections the calibration approach for this stage of the model begins with creating an observed set of From Home trips for each site. They were derived from :

- National Rail Travel Survey; and
- If no observed data is available a gravity-based approach based on costs will be used.

6.9.2 It should be noted that for SRTM for the majority of sites NRTS data was used and the gravity method was limited to only a few sites.

6.9.3 While these data sources was sufficient to establish patterns for trips, the magnitudes by tour was defined by the most up to date time period specific occupancy counts for each site from SPT surveys, aligned with tour proportions from the SHS data.

6.9.4 It has been shown in previous LATIS models that taking the road and PT assignment costs based on standard WebTAG parameters leads to a strong imbalance in choosing a site where travellers within this style of model attempt to minimise the PT leg of a Park and Ride journey as that has the largest impact on reducing the overall utility of a journey. To account for this, a weighting will be applied to the road and PT legs to increase the impact of the road and reduce the impact of the PT.

6.9.5 These were previously calibrated during development of SRM:12 as 0.55 for PT and 1.7 for road which gave a close approximation of choice between zone pairs compared to NRTS data. As the NRTS data has changed these parameters were re-evaluated with the most recent WebTAG generalised cost parameters. It was found that small changes in the PT Weight was necessary such that the distribution matched the observed data. This changed from 0.55 to 0.75.

6.9.6 To calibrate the site choice mechanism, the model was compared with the observed occupancy (which was consistent with the site specific occupancies used in the matrix derivation) and evaluated using the GEH statistic to establish a goodness of fit for the modelled and observed data.

6.9.7 Although neither WebTAG nor DMRB provides validation criteria for Park and Ride models of this style, the validation aimed to reduce the GEH values at all sites to a reasonable level while avoiding using heavily weighted site specific ASC values which could reduce sensitivity. The validation will be reviewed on a site by site basis for each time period. In the absence of specific WebTAG guidance, a target of a GEH of less than 5 to be achieved for at least 80% of sites was used. The results of this calibration is presented in Table 28.

Table 28. PnR GEH Statistics

BAND	AM GEH	LT GEH	SR GEH	PM GEH
<=1	37.1%	36.1%	35.1%	41.2%
1<x<=3	49.5%	45.9%	47.4%	44.8%
3<x<=5	9.8%	13.4%	13.4%	8.8%
>5	3.6%	4.6%	4.1%	5.2%
Total	100.0%	100.0%	100.0%	100.0%

6.9.8 Table 28 shows post calibration most of the sites appears to have a good match to that of the target usage.

7. TOUR AGGREGATION

7.1 Overview

7.1.1 While the demand model works in tours and considers directionality of trips (From Home and To Home), the assignment models work strictly in simple one-way trips in specific time periods and do not require any differentiation by direction, so a conversion process is required.

7.1.2 This stage takes the outputs from the standard Mode and Destination choice, Free Workplace Parking, Park and Ride, and Parking models. All these files detail trips by direction and mode.

7.1.3 The outputs of the Tour Aggregation component are matrix files which contain trips by direction, with From-Home and To-Home in .FHS and .THS files respectively. There are five files for each direction each denoting a different user class and containing 20 tables (4 modes by 5 time periods).

7.1.4 A prerequisite step undertaken is the conversion of the demand matrices from demand segments to user-classes. This definition is presented in Table 1 – Demand Segment Correspondence.

7.2 Calculation Steps

7.2.1 The first step of this element of the model combines the simple tour user class demand into their time period specific matrices based on aggregations of tours, separated by mode. The calculation of time period matrices is relatively straightforward and again is based on the principle of summing across the rows and columns of the 'Tour Grid' shown below. Note that the model transposes the trips for the To-Home legs in order to ensure the direction of the trips (from original destination to original origin) is correct.

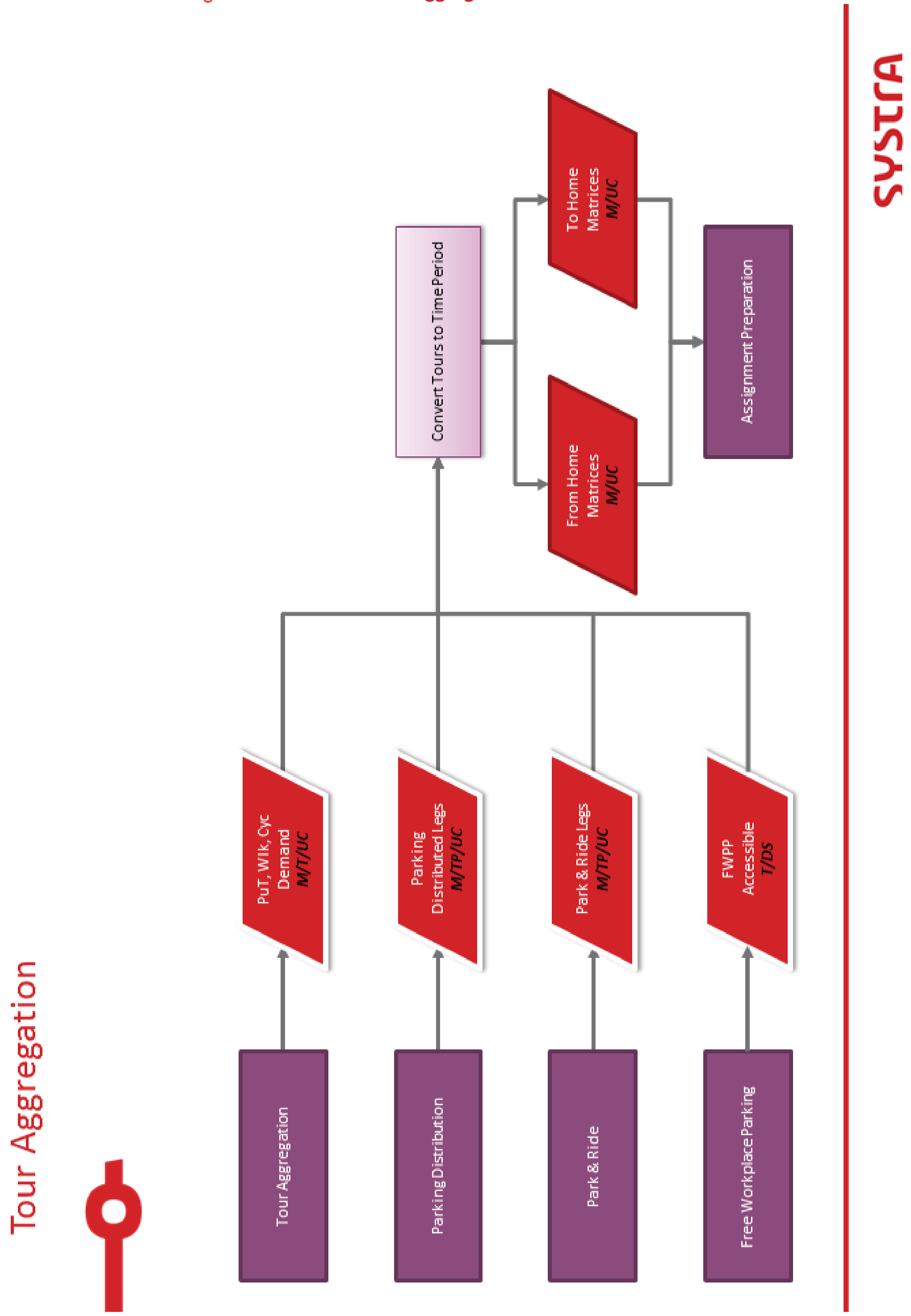
Table 29. Tour Grid

		INBOUND TIME PERIOD				
		AM	LT	SR	PM	OP
Outbound Time Period	AM	1	2	3	4	5
	LT	6	7	8	9	10
	SR	11	12	13	14	15
	PM	16	17	18	19	20
	OP	21	22	23	24	25

7.2.2 The application of these steps uses clustering according to groups to reduce runtimes.

7.2.3 The process is illustrated overleaf in Figure 29.

Figure 29. **Tours Aggregation Processes**



8. ASSIGNMENT PREPARATION

8.1 Overview

8.1.1 Assignment preparation converts demand model matrices into a format suitable for use in the assignment model, in particular converting to vehicles and converting to average peak hours.

8.1.2 As well as these steps, any final alterations to the assignment matrices are undertaken including accounting for external trips, special zones, and delta adjustment.

8.2 Inputs

8.2.1 The inputs to this component are the From-Home and To-Home matrices from the Tour Aggregation model and the One Way matrices (.OWS) from the One Way element of the model. These matrices are provided by time period and by user class.

8.2.2 Parameters will be taken in from the Params folder and include:

- Period to Hour factors;
- Journey Purpose to Ticket Type;
- Car User to Car Driver (CUCD) factors; and
- Delta adjustments.

8.2.3 In addition, add-in matrices are taken in from the input demand folder which reflect external trips, airport movements, and goods vehicle trips, disaggregated by mode and time period.

8.3 Parameter Derivation

Period to Hour Factors

8.3.1 The factors have been derived from analysis of observed count data at cordons / screenlines for the road and public transport modes. These have been reported via the appropriate assignment model development report.

Journey Purpose to Ticket Type (Public Transport) Factors

8.3.2 In order to evaluate the travel choices made using PT, the assignment model uses an expanded set of user classes to distinguish season ticket holders and standard ticket holders for commute and "other" travel purposes.

8.3.3 This essentially expands these each user classes into a season and non-season component. Within the PT assignment an eighth user class is also created, zero demand, which is used to speed up runtime but does not get discussed further here.

These parameters have been sourced from the Passenger Demand Forecasting Handbook and are reported through the *SRTM Public Transport Model Development Report Section 1.2.*

Car User to Car Driver (CUCD) Factors

8.3.4 There is a requirement to convert persons into vehicles for the car road assignments and this is done through the application of car user to car driver factors.

8.3.5 These factors have be calculated from the Scottish Household Survey and their derivation has been reported through Chapter 3.

8.3.6 The values for education have been calculated through analysis of DfT car occupancy statistics (NTS0906), and have similarly been reported in Chapter 3.

Delta Adjustments

8.3.7 The delta adjustments will be calculated based on the estimated assignment matrices, where a 'mask' is produced to align demand model outputs with the estimated assignment matrices.

8.3.8 This approach involves either one of two types of increment being created, specifically:

- Where the factor $0.5 < M = \frac{C}{P} < 2$, the multiplicative factor $M = \frac{C}{P}$ will be applied such that $O = MP$;
- Where the factor $0.5 > M = \frac{C}{P} > 2$, an additive adjustment $A = C - P$ will be applied such that $O = \max(0, P + A)$.

Where

C is the calibrated assignment matrix,
P is the output assignment matrix from the demand model prior to the adjustment,
O is the output assignment matrix from the demand model,
M is the multiplicative delta adjustment, and
A is the additive delta adjustment.

8.4 Outputs

8.4.1 The outputs from the Assignment Preparation stage are the assignment matrices by mode (4), user class (5), and time period (5) which consist of individual files by mode and time period.

8.5 Calculation Steps

8.5.1 There are four processes in this module which undertake the following steps:

- Directional aggregation;
- Period to hour factoring and vehicle conversion;
- Delta adjustment; and
- Include add-ins and prepare final assignment matrices.

8.5.2 The directional aggregation is a simple summation by the user class and time period of the outputs from the previous step, while the period to hour conversion multiplies by factors which differentiate by time period and mode. These factors could also be distinguished by spatial area but it is not recommended that this be the case initially. The road assignment matrices must also be converted from person trips to vehicle trips using the car user to car driver factors noted above.

8.5.3 A delta adjustment is required to avoid unnecessary model noise, in particular by ensuring the base year costs (which are an input to the demand model) can be replicated by the assignment models. The adjustment can be either additive or multiplicative dependent on the magnitude of the difference. In particular, where the observed target is greater than twice or less than half of the modelled result (on a cellular basis) an additive adjustment is used.

8.5.4 Finally, add-ins which cover special zones trips (essentially the outputs of the airport passenger model), external matrices and goods vehicles matrices are included in the assignment matrices by straight replacement or inclusion where appropriate. This aspect also undertakes a bucket rounding procedure which reduces runtimes of the assignment models. Special zones are included within the add-in matrices, as they are fixed in terms of the demand model calculations and must be accounted for in forecast year using an offline process.

SYSTRA

9. GENERALISED COST CALCULATION

9.1 Overview

9.1.1 The Generalised Cost Calculation stage takes costs from the assignment models and processes the costs for use within the next loop of the demand model. This requires the conversion of costs calculated from the assignment networks into the correct format for the demand model, focussed on creating tour-based costs and including the impact of parking measures.

9.1.2 Information regarding generalised cost calculations for each assignment model can be found:

- SRTM Road Model Development Report, SYSTRA, 2019 Section 5.4
- SRTM PT Model Development Report, SYSTRA, 2019 Section 3.7

9.2 Inputs

9.2.1 The inputs of this process are the generalised cost skims from each of the three assignment models (road, PT, and active) by mode, (assignment) user class and time period. In addition to these outputs from the previous stages of the model, the generalised cost procedures also read in the site file descriptions for both Park and Ride and Parking Distribution.

9.3 Outputs

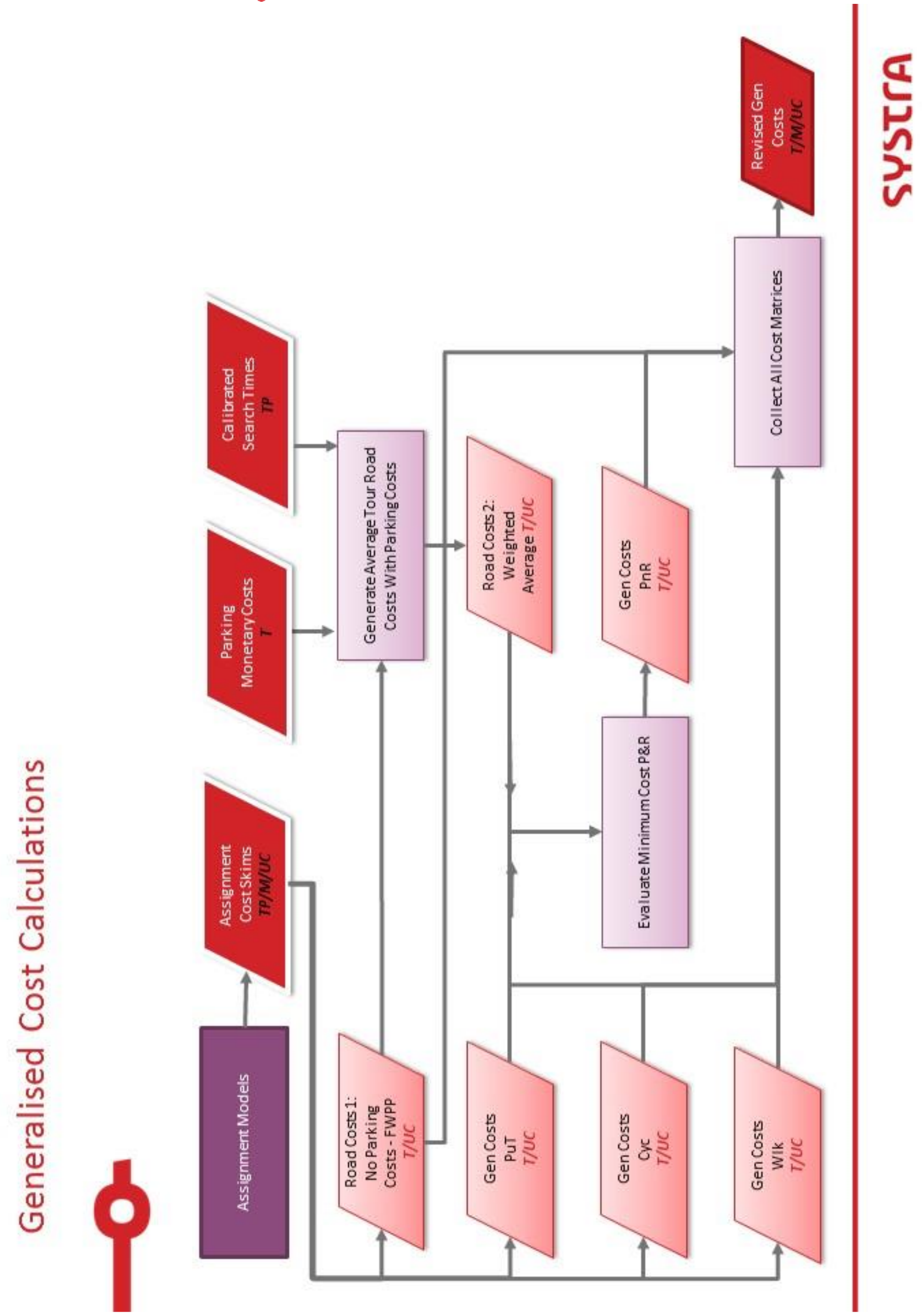
9.3.1 The outputs of this step will be five user class specific sets of average generalised cost matrices (.AGC's) which contain 125 tables segmented by tours (25) and mode (five).

9.4 Calculation Steps

9.4.1 The calculation steps undertaken by the generalised cost process are illustrated overleaf in Figure 30.

9.4.2 The first step in this process takes each of the four assigned modes cost skims and creates tour-based costs by summing the outbound leg and the inbound leg (transposed) for each of the 25 combinations of time periods and dividing by two.

Figure 30. **Generalised Cost Process**



9.4.4 As described earlier, the model undertakes assignments (and hence generates generalised cost matrices) for only three of the five time periods, hence assumptions for generalised costs for time periods which are not assigned in the present version of the model have to be made, specifically:

- The two IP time periods within the demand model will be fed identical costs;
- The off-peak road mode cost matrices are sourced from the LT assignment
- The off peak public transport model cost matrices are copied from the LT but with an additional 12 minutes time added to account of the lower service frequency; and
- The off peak active modes cost matrices will be assumed to be identical to the IP matrices.

9.4.5 The assignment costs are skimmed from the network by mode for each user class and time period, with the output matrices obtained in terms of generalised minutes.

9.4.6 Parking costs are defined as two separate inputs, the first being the user supplied parking charges per zone per tour. These reflect the monetary costs of parking.

9.4.7 The second set of costs are the calibrated search time costs, as detailed in Chapter 5.

9.4.8 Park and Ride generalised costs will be calculated using the utility defined in Chapter 6 and based on the minimum cost path of available sites rather than a logsum or weighted average cost.

9.4.9 The road and PT costs are based on the specific user class values but this is not consistent with the Park and Ride site choice model. The site choice model will use a single 'Total' user class which considers only commute costs.

9.4.10 Where Park and Ride is not included in the model (for example, no car available trips), an arbitrary cost of 9999 generalised minutes has been set within the cost matrices.

10. MODEL CONVERGENCE

10.1 Overview

10.1.1 A measure must be made on how well the demand model loop has converged to establish when to end the model, and this will be undertaken based on a comparison of costs and demand (GAP convergence) from each successive loop of the model. Note that only the four main modes (road, PT, walk and cycle) are considered in this comparison.

10.2 Inputs

10.2.1 The inputs to this model are the road, PT, walk and cycle generalised costs and assignment matrices from both the current and previous demand model loop. These are segmented by time period and user class. It should be noted that there may not be a complete correlation in user classes between modes, however aggregation of certain user classes will allow a like-for-like comparison.

10.3 Outputs

10.3.1 The output of this module is a single print file which details GAP convergence on every successive loop.

10.4 Calculation Steps

10.4.1 Convergence of the demand model is evaluated using GAP analysis. On each external loop of the demand model a process of trip damping takes place, combining 50% of the current matrix with 50% of the previous loops matrix. This is similar in effect to the 'fixed step' approach adopted in DIADEM and recommended in WebTAG guidance (WebTAG Unit M2 Chapter 6).

10.4.2 GAP analysis is undertaken on these outputs, which is a standard measure of convergence for supply and demand systems. This is defined as:

$$GAP = 100\times\frac{\sum_{ij} C_{ij}\left|T_{ij} - T_{ij}'\right|}{\sum_{ij} C_{ij}T_{ij}'}$$

where:

GAP is the GAP statistic;
C_{ij} is the generalised cost on the previous demand model loop;
T_{ij} are the trips on the previous demand model loop; and
T_{ij}' are the trips on the current demand model loop.

For the convergence criteria WebTAG guidance states "that gap values of less than 0.1% can be achieved in many cases, although in more problematic systems this may be nearer to 0.2%". In line with this, the convergence is considered acceptable when GAP<0.1% but this can be changed depending on runtimes implications.

11. DEMAND MODEL CALIBRATION APPROACH

11.1 Overview

11.1.1 The demand model calibration approach requires a set of costs to initialise the process

11.1.2 For the Phase 1 model, these costs have been sourced from the assignment of expanded TMfS trip matrices to the prevailing network models for the Phase 1 interim model.

11.1.3 For the final model, reported in this document, the model calibration used costs from the Phase 2 networks when assigned by the Phase 1 estimated matrices.

11.1.4 Spread values from WebTAG guidance, documented in the following chapter, have been run through an initial run of the demand model, with no parking or park and ride choice modelled and with no K factors included.

11.1.5 The park and ride and parking modules were then included and adjustments and K factors then calculated to ensure that the central area public transport trip distribution is broadly replicated.

11.1.6 Finally, the demand model was rerun with the final assignment model cost matrices and the lambda values modified and the remaining demand model adjustment parameters (alpha, beta, ASCs (cost constant) and IZM (Intrazonal cost constant) have been calibrated to obtain a 'best fit' with the observed data.

11.1.7 The 'best fit' with the observed data was defined using the following three metrics:

- Comparison with SHS / Census observed generalised cost curves;
- Comparison with SHS / Census observed trip length curves; and
- Elasticity with respect to both fuel and fares to be broadly consistent with guidance.

11.1.8 The procedure of adjusting the calibration parameters (Alpha, Beta, ACS & IZM) are made after evaluating the modelled mode share, intrazonal proportions and cost distribution by demand segment. Through an automated process, small incremental changes to the parameters were tested against the observed data where there was a gap. The Alpha and Beta were adjusted if there was a discrepancy in average generalised cost and ACS adjusted if the mode share differed. The intrazonal parameters were also adjusted to reflect their proportion in the observed data by demand segment.

11.1.9 The iterative process between the parameters were such that the distributions are matched to an acceptable level first, following a mode share adjustment. This was repeated until a plausible match was achieved. The number of iterations for each parameter within a calibration loop was set according to how much each diverted away from the observed data. Manual adjustments were implemented if it deemed necessary

11.2 Calibration Stages

11.2.1 The table below illustrates the WebTAG sourced scaling and lambda parameters used in the initial calibration run of the model. This model had K factors set to 1.

Table 30. Starting Lambda Parameters

REF	PUR	RETIRED	CAR AVAIL	SCALE	CAR	PT	PNR	WLK	CYC
1	EMP	Non-Retired	All	0.45	0.067	0.036	0.036	0.067	0.067
2	COM	Non-Retired	Car	0.68	0.065	0.033	0.033	0.065	0.065
3	COM	Non-Retired	No car	0.68	0.065	0.033	0.033	0.065	0.065
4	OTH	Non-Retired	Car	0.53	0.090	0.036	0.036	0.090	0.090
5	OTH	Non-Retired	No car	0.53	0.090	0.036	0.036	0.090	0.090
6	EDU	Non-Retired	Car	0.53	0.090	0.036	0.036	0.090	0.090
7	EDU	Non-Retired	No car	0.53	0.090	0.036	0.036	0.090	0.090
8	ALL	Retired	Car	0.53	0.090	0.036	0.036	0.090	0.090
9	ALL	Retired	No car	0.53	0.090	0.036	0.036	0.090	0.090
10	EMP	All	All	0.73	0.081	0.042	0.042	0.081	0.081
11	NHBO	All	Car	0.81	0.077	0.033	0.033	0.077	0.077
12	NHBO	Non-Retired	No car	0.81	0.077	0.033	0.033	0.077	0.077
13	EMP	Non-Retired	All	0.45	0.067	0.036	0.036	0.067	0.067
14	COM	Non-Retired	Car	0.68	0.065	0.033	0.033	0.065	0.065
15	COM	Non-Retired	No car	0.68	0.065	0.033	0.033	0.065	0.065
16	OTH	Non-Retired	Car	0.53	0.090	0.036	0.036	0.090	0.090
17	OTH	Non-Retired	No car	0.53	0.090	0.036	0.036	0.090	0.090
18	EDU	Non-Retired	Car	0.53	0.090	0.036	0.036	0.090	0.090
19	EDU	Non-Retired	No car	0.53	0.090	0.036	0.036	0.090	0.090
20	ALL	Retired	Car	0.53	0.090	0.036	0.036	0.090	0.090
21	ALL	Non-Retired	No car	0.53	0.090	0.036	0.036	0.090	0.090

Source: WebTAG Unit M2 Tables 5.1 and 5.2

11.2.2 The Phase 2 model calibration began by using the parameters calculated during the Phase 1 model calibration, with costs from the Phase 2 network models assigned with Phase 12 estimated matrices and K factors reset to 1.

11.2.3 The initial Phase 2 scaling, alpha and mode constants are as indicated below:

Table 31. Adjusted Lambda Parameters (Stage 1 Parameter Calibration)

DS	DEMAND SEGMENT	PARAMETER: LAMBDA PARAMETERS					
		MODE	CAR	PUT	PNR	WLK	CYC
1	Employer's Business	0.45	-0.067	-0.036	-0.036	-0.067	-0.067
2	Commute Car Available	0.68	-0.065	-0.033	-0.033	-0.065	-0.065
3	Commute No Car Available	0.68	-0.065	-0.033	-0.033	-0.065	-0.065
4	Other Car Available	0.53	-0.120	-0.050	-0.036	-0.090	-0.090
5	Other No Car Available	0.53	-0.090	-0.050	-0.036	-0.090	-0.090
6	Education Car Available	0.53	-0.090	-0.036	-0.036	-0.090	-0.090
7	Education No Car Available	0.53	-0.090	-0.036	-0.036	-0.090	-0.090
8	Retired Car Available	0.53	-0.120	-0.050	-0.036	-0.090	-0.090
9	Retired No Car Available	0.53	-0.090	-0.050	-0.036	-0.090	-0.090
10	Non Home Based Employer's Business	0.73	-0.081	-0.042	-0.042	-0.081	-0.081
11	Non Home Based Other Car Available	0.81	-0.100	-0.033	-0.033	-0.077	-0.077
12	Non Home Based Other No Car Available	0.81	-0.077	-0.033	-0.033	-0.077	-0.077

Table 32. Calibrated Demand Model- Alpha Parameters (Stage 1 Parameter Calibration)

DS	DEMAND SEGMENT	PARAMETER: ALPHA – FACTOR COST CHANGE				
		CAR	PUT	PNR	WLK	CYC
1	Employer's Business	1.1	0.9	1.0	0.5	3.6
2	Commute Car Available	1.2	0.9	1.0	0.8	1.1
3	Commute No Car Available	1.5	0.9	1.0	1.1	1.4
4	Other Car Available	1.2	0.9	1.0	0.4	0.8
5	Other No Car Available	1.5	0.9	1.0	0.6	0.9
6	Education Car Available	1.5	1.1	1.0	1.3	0.7
7	Education No Car Available	1.5	1.1	1.0	0.7	0.7
8	Retired Car Available	1.2	1.0	1.0	0.4	0.7
9	Retired No Car Available	1.5	1.1	1.0	0.5	0.8
10	Non Home Based Employer's Business	0.9	0.9	1.0	0.9	3.4
11	Non Home Based Other Car Available	1.3	0.9	1.0	0.5	1.6
12	Non Home Based Other No Car Available	1.5	0.9	1.0	0.5	1.8

Units: Factor applied to model costs

Table 33. Calibrated Demand Model- ASC Parameters (Stage 1 Parameter Calibration)

DS	DEMAND SEGMENT	PARAMETER: ASC – ABSOLUTE COST CHANGE				
		CAR	PUT	PNR	WLK	CYC
1	Employer's Business	-22.5	34.4	0.0	0.2	10.8
2	Commute Car Available	-1.0	8.6	0.0	-5.4	10.5
3	Commute No Car Available	0.0	40.3	0.0	-16.7	15.6
4	Other Car Available	-18.0	32.2	0.0	-13.4	10.6
5	Other No Car Available	0.0	22.5	0.0	-15.0	15.0
6	Education Car Available	36.7	28.6	0.0	-48.7	12.4
7	Education No Car Available	0.0	43.4	0.0	-31.7	13.9
8	Retired Car Available	-19.0	38.6	0.0	-15.6	1.8
9	Retired No Car Available	0.0	5.0	0.0	-10.0	15.0
10	Non Home Based Employer's Business	9.3	1.4	0.0	-16.8	5.4
11	Non Home Based Other Car Available	5.7	17.2	0.0	-22.0	2.5
12	Non Home Based Other No Car Available	0.0	20.5	0.0	-20.9	10.8

Units: Generalised Minutes

Table 34. Calibrated Demand Model- IZM Parameters (Stage 1 Parameter Calibration)

DS	DEMAND SEGMENT	PARAMETER: INTRAZONAL MATRIX COST CHANGE				
		CAR	PUT	PNR	WLK	CYC
1	Employer’s Business	-30.0	-23.1	30.0	-14.9	30.0
2	Commute Car Available	-4.7	18.4	30.0	-1.4	-12.4
3	Commute No Car Available	9.6	19.6	30.0	14.6	-2.5
4	Other Car Available	-10.2	5.7	30.0	-13.3	30.0
5	Other No Car Available	11.7	7.1	30.0	-6.8	1.1
6	Education Car Available	-27.9	-30.0	30.0	8.9	-5.0
7	Education No Car Available	11.3	-30.0	30.0	3.1	-9.0
8	Retired Car Available	-7.4	-11.0	30.0	-12.6	-30.0
9	Retired No Car Available	11.8	-15.4	30.0	-11.7	30.0
10	Non Home Based Employer's Business	-20.9	-19.3	30.0	12.3	30.0
11	Non Home Based Other Car Available	-11.5	-3.1	30.0	-3.6	7.3
12	Non Home Based Other No Car Available	10.2	-19.1	30.0	-6.8	30.0

Units: Generalised Minutes

11.2.4 The demand model was run with these inputs and produced the following mode shares and average generalised cost results.

Table 35. Demand Model Summary – Mode Shares – Costs from Phase 1 Estimated demand matrices assigned to SRTM Phase 2 networks

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
Employer’s Business	79.9%	10.4%	0.0%	9.5%	0.2%	100.0%	88.6%	5.3%	0.0%	6.1%	0.0%	100.0%
Commute Car Available	68.0%	21.8%	0.7%	7.5%	2.0%	100.0%	78.9%	14.6%	0.0%	5.8%	0.7%	100.0%
Commute No Car Available	0.0%	65.0%	0.0%	31.4%	3.5%	100.0%	0.0%	65.9%	0.0%	30.6%	3.5%	100.0%
Other Car Available	76.5%	3.6%	0.0%	18.9%	1.0%	100.0%	82.7%	3.6%	0.0%	13.5%	0.2%	100.0%
Other No Car Available	0.0%	27.6%	0.0%	68.4%	4.1%	100.0%	0.0%	31.0%	0.0%	67.4%	1.6%	100.0%
Education Car Available	62.2%	10.0%	0.0%	26.1%	1.6%	100.0%	26.9%	22.5%	0.0%	49.7%	0.9%	100.0%
Education No Car Available	0.0%	23.3%	0.0%	72.6%	4.1%	100.0%	0.0%	30.8%	0.0%	68.0%	1.3%	100.0%
Retired Car Available	75.4%	3.2%	0.0%	18.5%	2.8%	100.0%	84.5%	3.4%	0.0%	11.7%	0.4%	100.0%
Retired No Car Available	0.0%	40.2%	0.0%	56.2%	3.5%	100.0%	0.0%	46.4%	0.0%	53.1%	0.4%	100.0%
Non Home Based Employer's Business	64.0%	26.1%	0.0%	9.9%	0.0%	100.0%	66.5%	22.2%	0.0%	11.4%	0.0%	100.0%
Non Home Based Other Car Available	37.8%	24.0%	0.0%	37.8%	0.4%	100.0%	51.9%	22.9%	0.0%	24.9%	0.4%	100.0%
Non Home Based Other No Car Available	0.0%	35.0%	0.0%	64.7%	0.2%	100.0%	0.0%	45.1%	0.0%	54.3%	0.5%	100.0%

*Run Name: Costs sourced from **BY_P2A** – Default Lambda Parameters (**Table 30**) – Output Spreadsheet: **20170220_Full_MDC_Summary_1 0.xlsb***

Table 36. Demand Model Summary – Average Generalised Cost summary - Costs from Phase 1 Estimated demand matrices assigned to SRTM Phase 2 networks

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
Employer’s Business	28.6	313.3	0.0	48.4	0.0	0.0	25.2	104.4	9,999.0	45.5	23.9	0.0
Commute Car Available	25.7	131.1	0.0	64.1	40.7	0.0	24.7	119.4	9,999.0	146.2	44.2	0.0
Commute No Car Available	0.0	115.2	0.0	61.7	37.3	0.0	19.9	133.5	9,999.0	59.8	38.1	0.0
Other Car Available	14.6	129.9	0.0	45.4	48.0	0.0	13.9	93.2	9,999.0	43.5	47.3	0.0
Other No Car Available	0.0	117.9	0.0	44.9	46.0	0.0	15.1	128.5	9,999.0	37.1	44.2	0.0
Education Car Available	0.0	77.5	0.0	70.3	45.4	0.0	0.0	88.2	9,999.0	67.9	44.2	0.0
Education No Car Available	0.0	77.5	0.0	70.3	45.4	0.0	0.0	129.9	9,999.0	65.3	44.3	0.0
Retired Car Available	15.0	86.7	0.0	47.9	35.4	0.0	14.2	72.9	9,999.0	45.3	34.5	0.0
Retired No Car Available	0.0	84.1	0.0	45.3	51.7	0.0	15.1	96.9	9,999.0	32.8	50.1	0.0
Non Home Based Employer's Business	30.9	96.1	0.0	29.8	0.0	0.0	25.0	89.3	9,999.0	27.1	21.6	0.0
Non Home Based Other Car Available	15.2	135.5	0.0	47.1	31.7	0.0	15.3	114.5	9,999.0	43.8	34.3	0.0
Non Home Based Other No Car Available	0.0	138.9	0.0	48.9	30.3	0.0	17.3	127.3	9,999.0	46.5	34.4	0.0

*Run Name: Costs sourced from **BY_P2A** – Default Lambda Parameters (**Table 30**) – Output Spreadsheet: **20170220_Full_MDC_Summary_1 0.xlsb***

11.2.5 Visual inspection of the modelled and observed generalised trip cost distributions by demand segment revealed that minor adjustments of the lambda values would be required alongside the inclusion of parking and park & ride.

11.2.6 Furthermore, sector analysis revealed that the public transport model was not replicating the observed mode shares to central Glasgow. This was expected given the removal of the Phase 1 K factors and the non-inclusion of parking search times at this stage.

Lambda Adjustment and Initial Calibration

11.2.7 This calibration process used the processes outlined earlier to modify alpha and ASCs into the model to better fit the observed generalised cost distributions. Once this process was completed an inspection of the results was undertaken.

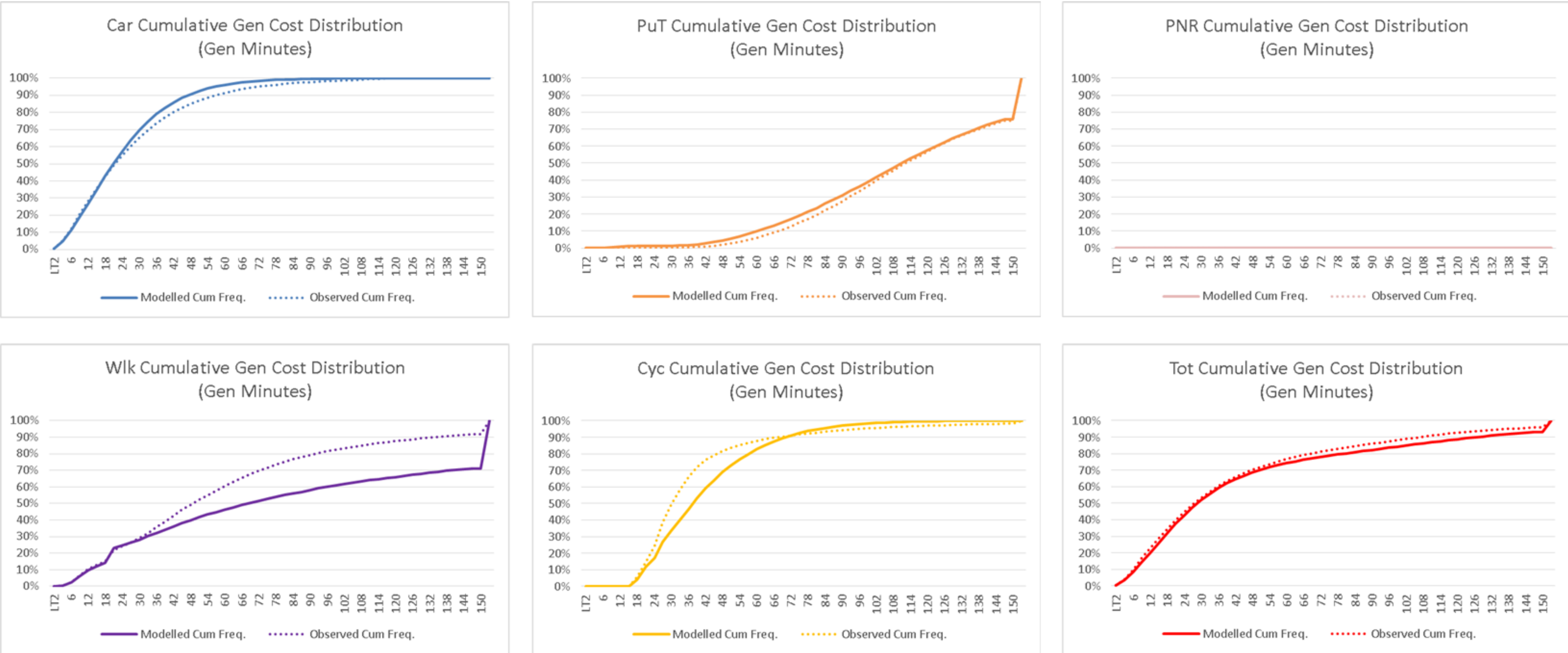
11.2.8 The results of these lambda changes are shown in the table below.

Table 37. Adjusted Lambda Parameters

DS	DEMAND SEGMENT	PARAMETER: LAMBDA PARAMETERS					
		MODE	CAR	PUT	PNR	WLK	CYC
1	Employer's Business	0.47	-0.067	-0.036	-0.036	-0.067	-0.067
2	Commute Car Available	0.70	-0.065	-0.033	-0.033	-0.065	-0.065
3	Commute No Car Available	0.68	-0.065	-0.033	-0.033	-0.065	-0.065
4	Other Car Available	0.55	-0.120	-0.050	-0.036	-0.090	-0.090
5	Other No Car Available	0.54	-0.090	-0.050	-0.036	-0.090	-0.090
6	Education Car Available	0.55	-0.090	-0.036	-0.036	-0.090	-0.090
7	Education No Car Available	0.55	-0.090	-0.036	-0.036	-0.090	-0.090
8	Retired Car Available	0.55	-0.120	-0.050	-0.036	-0.090	-0.090
9	Retired No Car Available	0.55	-0.090	-0.050	-0.036	-0.090	-0.090
10	Non Home Based Employer's Business	0.73	-0.081	-0.042	-0.042	-0.081	-0.081
11	Non Home Based Other Car Available	0.83	-0.100	-0.033	-0.033	-0.077	-0.077
12	Non Home Based Other No Car Available	0.83	-0.077	-0.033	-0.033	-0.077	-0.077

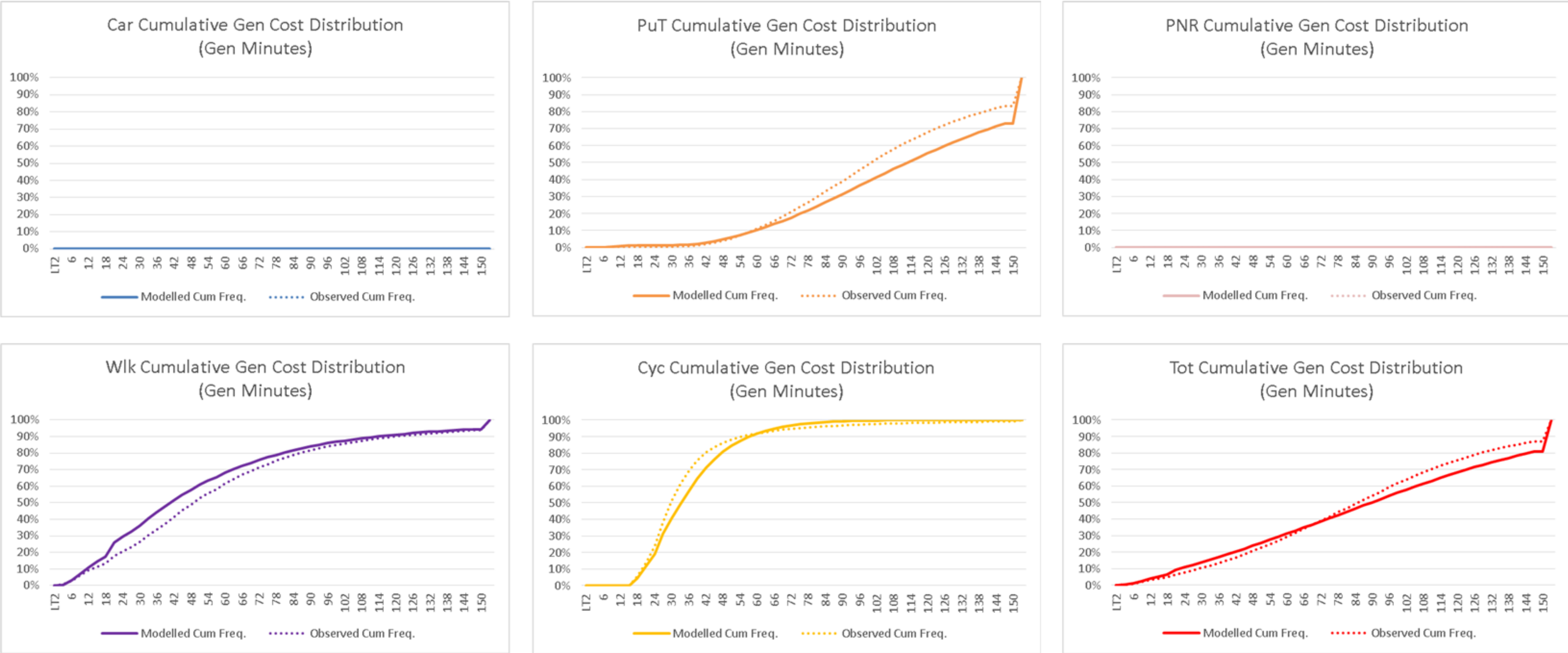
11.2.9 The red bolded cells in Table 37 indicate the lambda values that have changed from the default WebTAG parameters during this calibration run.

Figure 31. **Commute Car Av. Generalised Cost Curve Comparison – Pre-Parking Calibration**



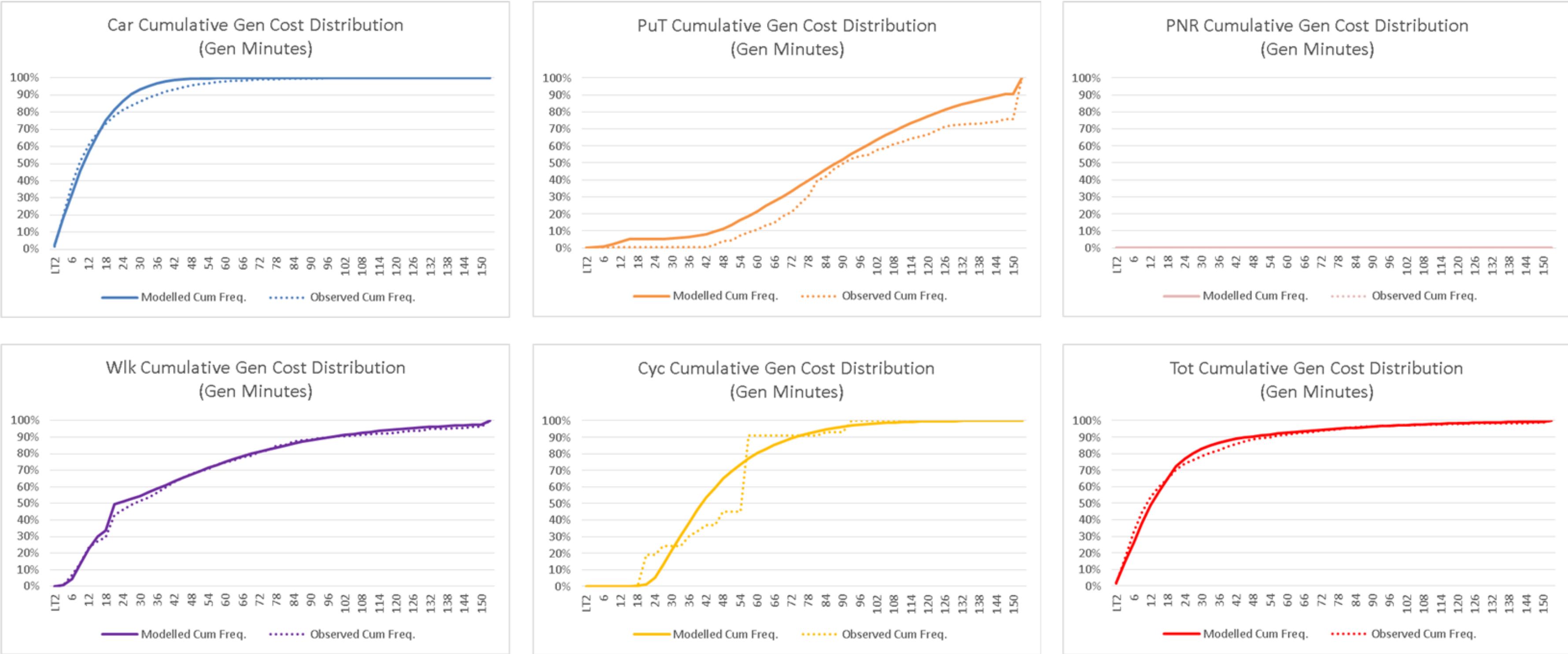
*Run Name: Costs sourced from **BY_P2A** – Default Lambda Parameters (**Table 30**) – Output Spreadsheet: **20170220_Full_MDC_Summary_1 3.xlsb***

Figure 32. **Commute No Car Av. Generalised Cost Curve Comparison - Pre-Parking Calibration**



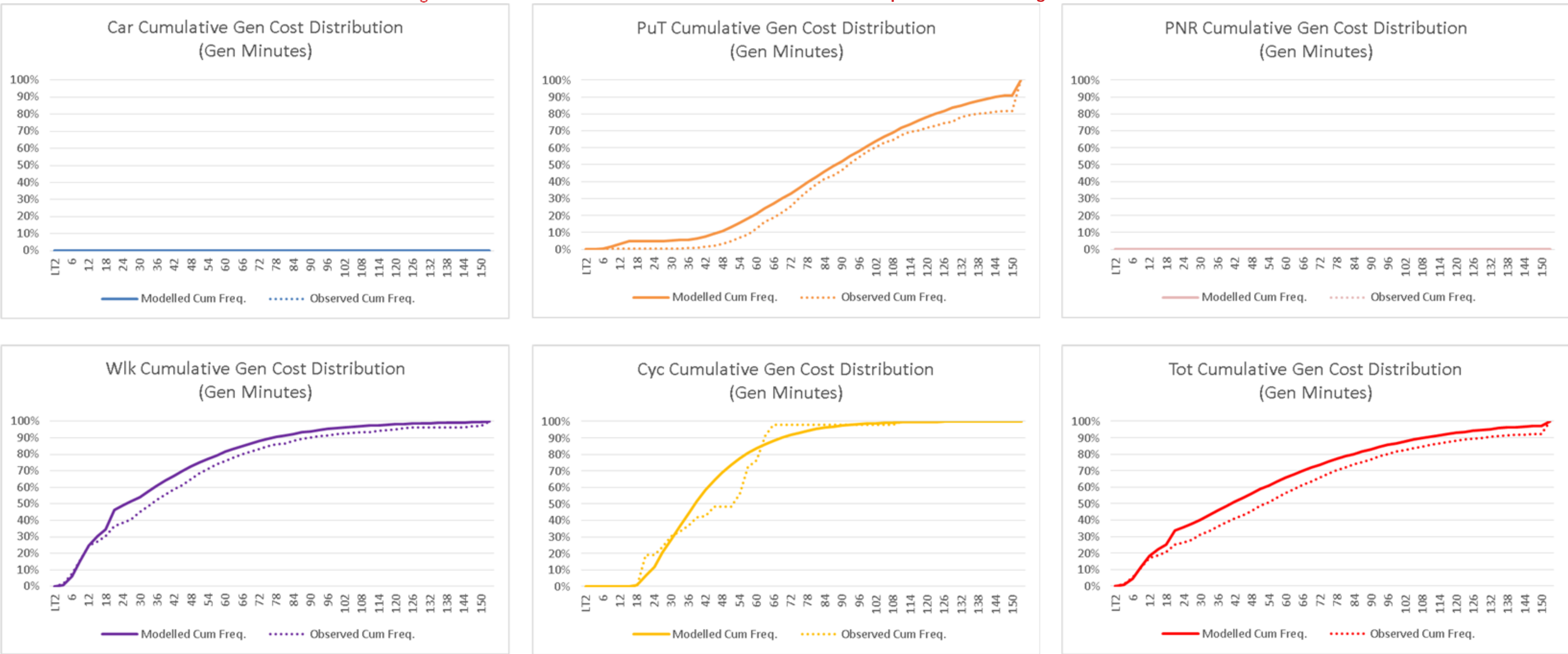
Run Name: Costs sourced from ***BY_P2A*** *– Default Lambda Parameters (****Table 30****) – Output Spreadsheet:* ***20170220_Full_MDC_Summary_1 3.xlsb***

Figure 33. **Other Car Av. Generalised Cost Curve Comparison – Pre Parking Calibration**



Run Name: Costs sourced from ***BY_P2A*** *– Default Lambda Parameters (****Table 30****) – Output Spreadsheet:* ***20170220_Full_MDC_Summary_1 3.xlsb***

Figure 34. **Other No Car Av. Generalised Cost Curve Comparison - Pre Parking Calibration**



*Run Name: Costs sourced from **BY_P2A** – Default Lambda Parameters (**Table 30**) – Output Spreadsheet: **20170220_Full_MDC_Summary_1 3.xlsb***

Table 38. Demand Model Summary – Mode Shares - Pre Parking Calibration

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
Employer's Business	81.7%	9.5%	0.0%	8.7%	0.1%	100.0%	88.6%	5.3%	0.0%	6.1%	0.0%	100.0%
Commute Car Available	70.9%	21.3%	0.0%	6.6%	1.2%	100.0%	78.9%	14.6%	0.0%	5.8%	0.7%	100.0%
Commute No Car Available	0.0%	65.2%	0.0%	31.7%	3.1%	100.0%	0.0%	65.9%	0.0%	30.6%	3.5%	100.0%
Other Car Available	77.5%	3.2%	0.0%	18.3%	0.9%	100.0%	82.7%	3.6%	0.0%	13.5%	0.2%	100.0%
Other No Car Available	0.0%	26.5%	0.0%	69.5%	4.0%	100.0%	0.0%	31.0%	0.0%	67.4%	1.6%	100.0%
Education Car Available	19.4%	21.4%	0.0%	55.9%	3.3%	100.0%	26.9%	22.5%	0.0%	49.7%	0.9%	100.0%
Education No Car Available	0.0%	21.8%	0.0%	74.2%	4.0%	100.0%	0.0%	30.8%	0.0%	68.0%	1.3%	100.0%
Retired Car Available	76.1%	3.0%	0.0%	18.2%	2.7%	100.0%	84.5%	3.4%	0.0%	11.7%	0.4%	100.0%
Retired No Car Available	0.0%	39.2%	0.0%	57.3%	3.4%	100.0%	0.0%	46.4%	0.0%	53.1%	0.4%	100.0%
Non Home Based Employer's Business	65.2%	25.1%	0.0%	9.6%	0.0%	100.0%	66.5%	22.2%	0.0%	11.4%	0.0%	100.0%
Non Home Based Other Car Available	37.8%	23.9%	0.0%	37.9%	0.4%	100.0%	51.9%	22.9%	0.0%	24.9%	0.4%	100.0%
Non Home Based Other No Car Available	0.0%	34.3%	0.0%	65.5%	0.2%	100.0%	0.0%	45.1%	0.0%	54.3%	0.5%	100.0%

*Run Name: Costs sourced from **BY_P2A** – Default Lambda Parameters (**Table 30**) – Output Spreadsheet: **20170220_Full_MDC_Summary_1 3.xlsb***

Table 39. Demand Model Summary – Average Generalised Cost – Pre Parking Calibration

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
Employer's Business	27.6	313.3	0.0	48.4	0.0	0.0	25.1	104.3	9,999.0	45.3	23.9	0.0
Commute Car Available	28.6	131.1	0.0	64.1	40.7	0.0	25.6	118.4	9,999.0	123.7	43.5	0.0
Commute No Car Available	0.0	115.2	0.0	61.7	37.3	0.0	20.1	120.6	9,999.0	59.8	38.1	0.0
Other Car Available	15.7	129.9	0.0	45.4	48.0	0.0	13.9	93.2	9,999.0	43.2	47.2	0.0
Other No Car Available	0.0	117.9	0.0	44.9	46.0	0.0	15.2	93.1	9,999.0	37.1	44.2	0.0
Education Car Available	6.3	77.5	0.0	70.3	45.4	0.0	13.1	91.0	9,999.0	69.0	44.8	0.0
Education No Car Available	0.0	77.5	0.0	70.3	45.4	0.0	15.0	88.7	9,999.0	65.2	44.3	0.0
Retired Car Available	15.7	86.7	0.0	47.9	35.4	0.0	14.2	72.8	9,999.0	45.0	34.4	0.0
Retired No Car Available	0.0	84.1	0.0	45.3	51.7	0.0	15.2	66.6	9,999.0	32.8	50.1	0.0
Non Home Based Employer's Business	31.9	96.1	0.0	29.8	0.0	0.0	24.1	89.3	9,999.0	27.0	21.6	0.0
Non Home Based Other Car Available	17.7	135.5	0.0	47.1	31.7	0.0	15.2	114.7	9,999.0	43.6	34.2	0.0
Non Home Based Other No Car Available	0.0	138.9	0.0	48.9	30.3	0.0	17.4	108.5	9,999.0	46.5	34.4	0.0

*Run Name: Costs sourced from **BY_P2A** – Default Lambda Parameters (**Table 30**) – Output Spreadsheet: **20170220_Full_MDC_Summary_1 3.xlsb***

11.2.10 The change in the parameters principally affected the car available education trips, though some small changes were also observed in the mode shares of other demand segments.

11.2.11 The parking model was then added into the demand model calibration process.

Introduction of Parking

11.2.12 The inclusion of the free workplace parking and the parking capacity models required the coding of three additional input files listed below, and a number of parameters specified through the Cube catalog.

- Value of times, as used in the derivation of the road generalised cost equation;
- Free Workplace Parking Spaces (as defined in section 4.5); and
- Public Parking Spaces and Charges (as defined in section 5.3).

11.2.13 Free workplace parking enables demand from the car available commuting demand segment to access free parking within the parking area, followed by a secondary mode choice for those trips that have not been satisfied. The following four images illustrate the free workplace parking occupancy at the end of each time period.

Figure 35. FWPP Occupancy at end of AM time period

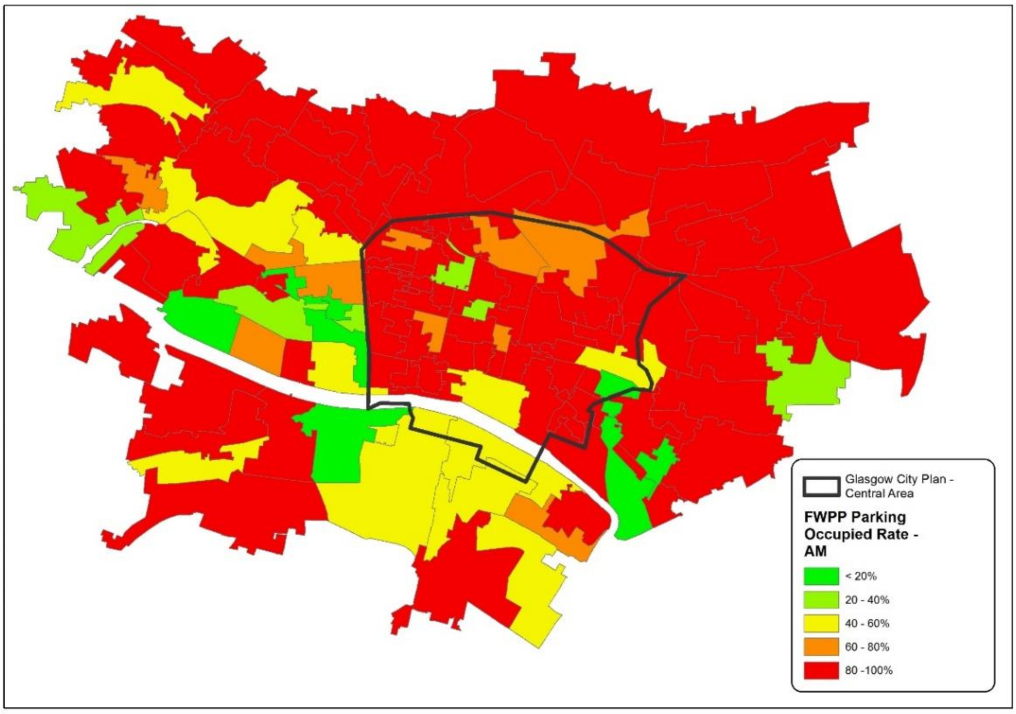


Figure 36. **FWPP Occupancy at end of LT time period**

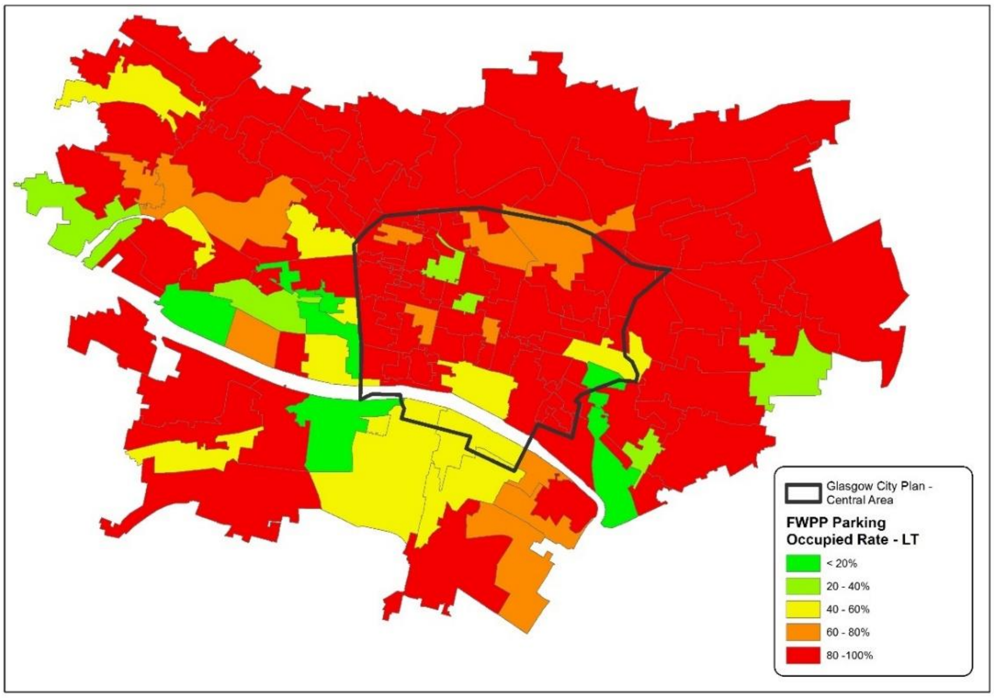


Figure 37. **FWPP Occupancy at end of SR time period**

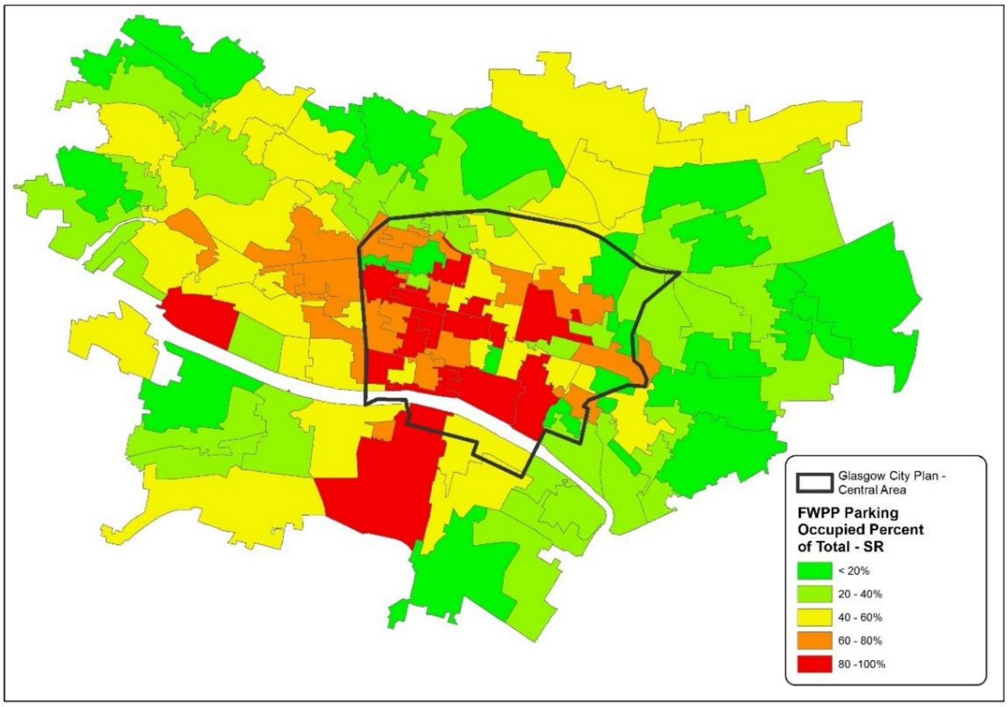
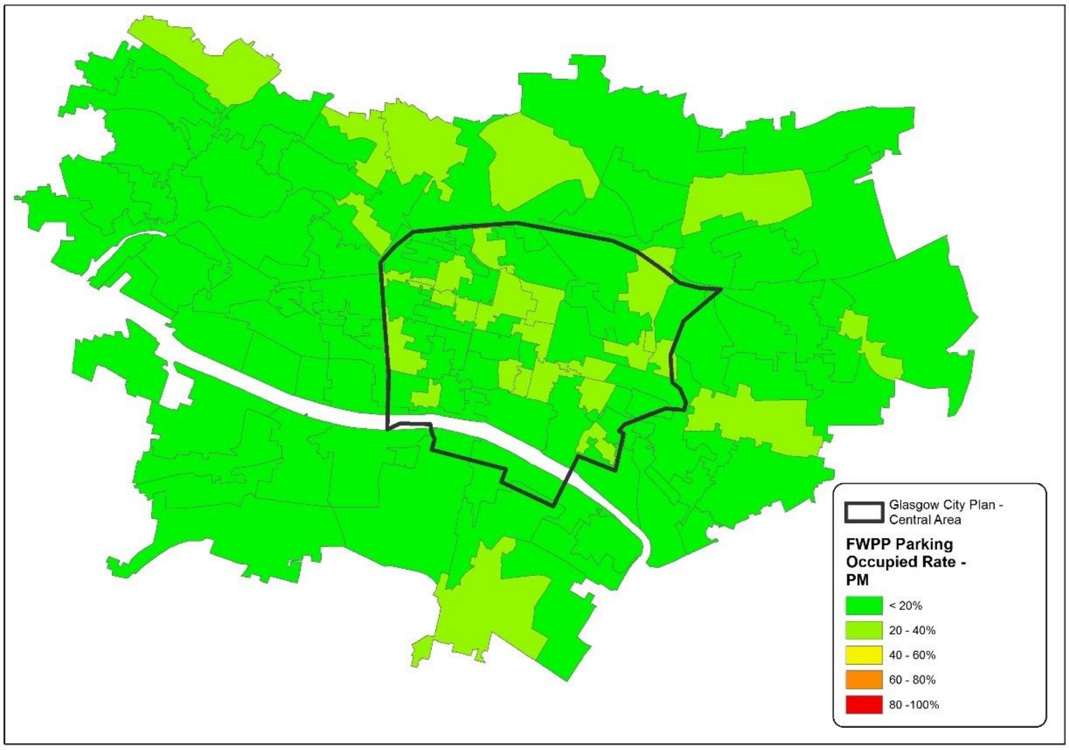


Figure 38. **FWPP Occupancy at end of PM time period**



11.2.14 The four images reveal as expected, a generally full usage of free workplace parking by the end of the morning peak. These spaces continued to be well used throughout the day until the end of the evening peak when the commuters return home.

11.2.15 There are a couple of 'low usage' zones at the end of the AM period, these are:

- St. Enoch centre and south of Glasgow Central station;
- Between West Regent Street and West George Street to the north of Glasgow Central station;
- South of Cowcaddens Subway / High Street; and
- Vacant land adjacent to Glasgow High Street station.

11.2.16 Overall, the level of usage is plausible, especially for the core central area of Glasgow. A summary of the overall level of demand within the central area is given below.

Table 40. Summary results – Free Workplace Parking

MEASURE	VALUE	% OF CAPACITY
FWPP Capacity	29209	
Parked trips at end of AM time period	18404	63%
Parked trips at end of LT time period	18764	64%
Parked trips at end of SR time period	16719	57%
Parked trips at end of PM time period	3471	12%

11.2.17 Overall, 63% of free workplace parking is used at the end of the morning peak period across the modelled area, with proportionately higher use within the central core.

11.2.18 In addition, a check of the outcome of the secondary mode choice was performed. As discussed in the methodology (section 5.5), the default parking charges per zone per hour, multiplied by the assumed duration of the tour, is applied to the road costs. This results in a substantial increase in travel costs for road for trips destined to the central area zones.

Table 41. Demand Model Summary – pre and post Free Workplace Parking Comparison

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
MODE SHARES												
Commute Car Available (pre FWPP)	70.9%	21.3%	0.0%	6.6%	1.2%	100.0%	79.0%	14.6%	-	5.7%	0.7%	100.0%
Commute Car Available (post FWPP)	73.2%	20.1%	0.0%	5.6%	1.1%	100.0%	79.0%	14.6%	-	5.7%	0.7%	100.0%
AVERAGE GENERALISED COST												
Commute Car Available (pre FWPP)	28.6	131.1	0.0	64.1	40.7	0.0	25.7	120.2	-	81.0	42.4	0.0
Commute Car Available (post FWPP)	26.6	131.1	0.0	66.8	41.6	0.0	25.7	120.2	-	81.0	42.4	0.0

*Run Name: Costs sourced from **BY_P2A** – Default Lambda Parameters (**Table 30**) – Output Spreadsheet: **20170220_Full_MDC_Summary_1 4.xlsb***

11.2.19 The next stage in the demand model calibration was the estimation of the search time component of parking costs.

11.2.20 The calibration of the parking search time was an iterative process by adjusting 3 parking calibration parameters until the model converges to a satisfactory level. These calibration parameters are:

- A maximum search time that is applied when the capacity of a zone is more than equal to 100% (PDist_MaxST);
- A minimum search time that is applied to ensure that the model does not divide by zero; and
- A scaling factor (Pdist_Scale) to adjust the increase as occupancy levels rise.

11.2.21 The equation establishing the search time by zone explained in section 5.5.11, was used to test the effect of search time on the parking demand. There were two main factors that were assessed in order to derive a suitable set of parking calibration parameters, as follows:

- Successful convergence of the demand model as a result of changes in the parking costs, and
- Limiting oscillations between low and high search times.

11.2.22 The parameters obtained were a value of 16 minutes for the maximum search time, 0.5 minutes for the minimum search time and a scaling factor of 1.16. The figures below shows the result of various checks which involved the convergence.

Figure 39. **Parking Search Time Distribution**

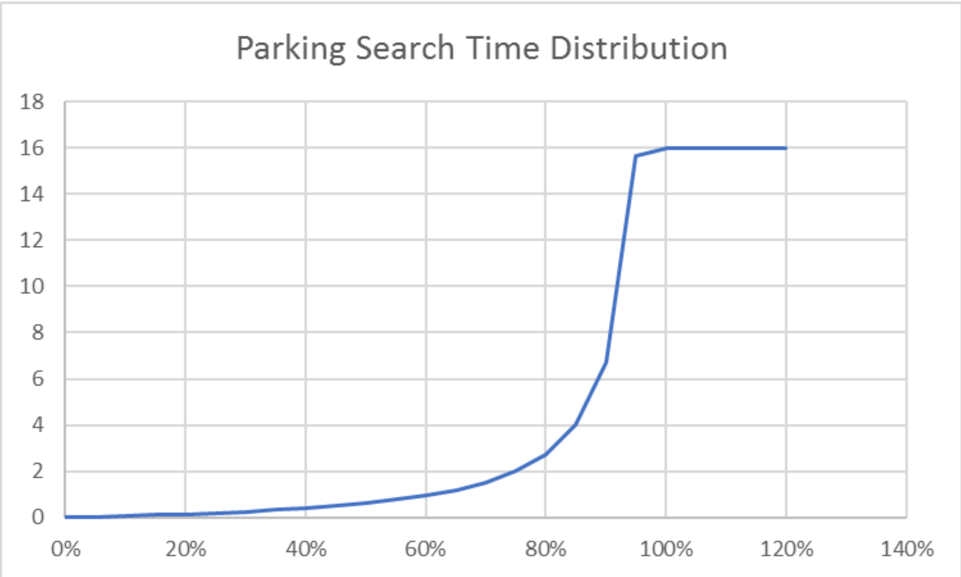


Figure 40. **Search Times - AM**

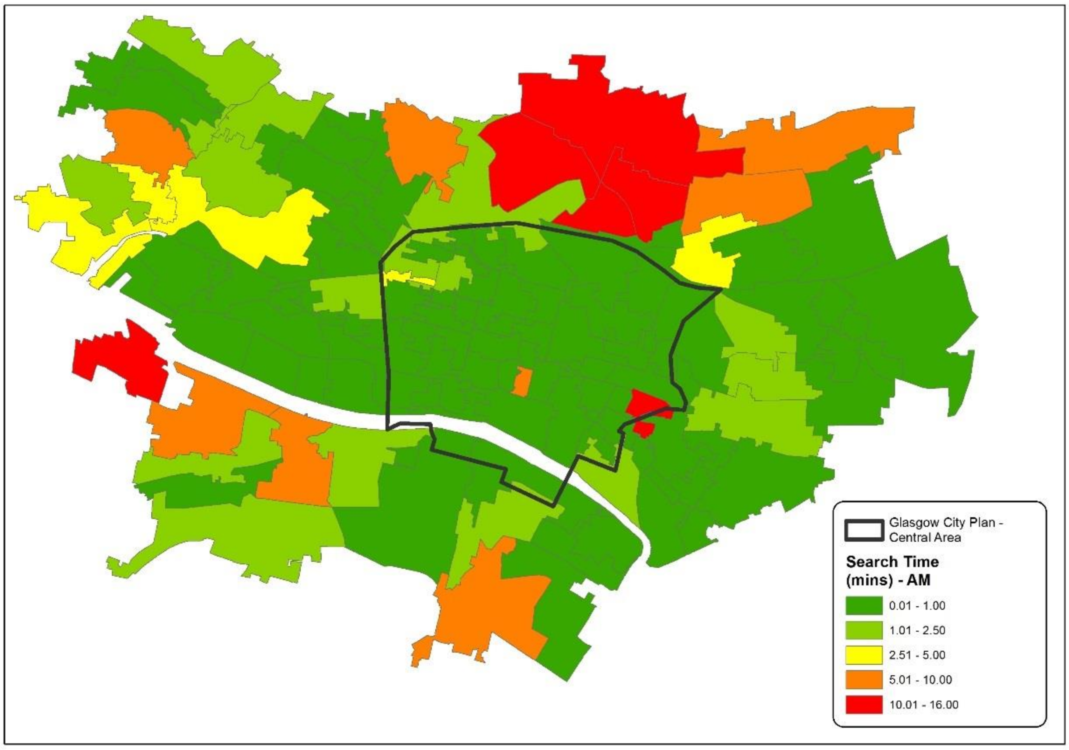


Figure 41. **Search Time – LT**

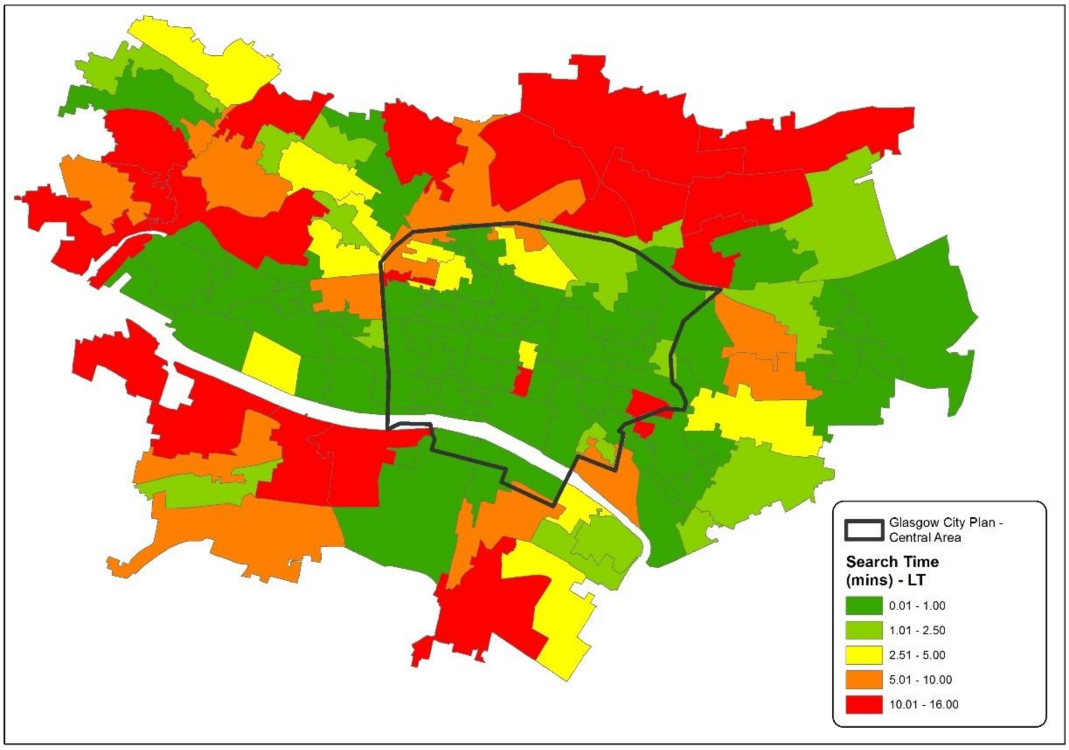


Figure 42. **Search Time – SR**

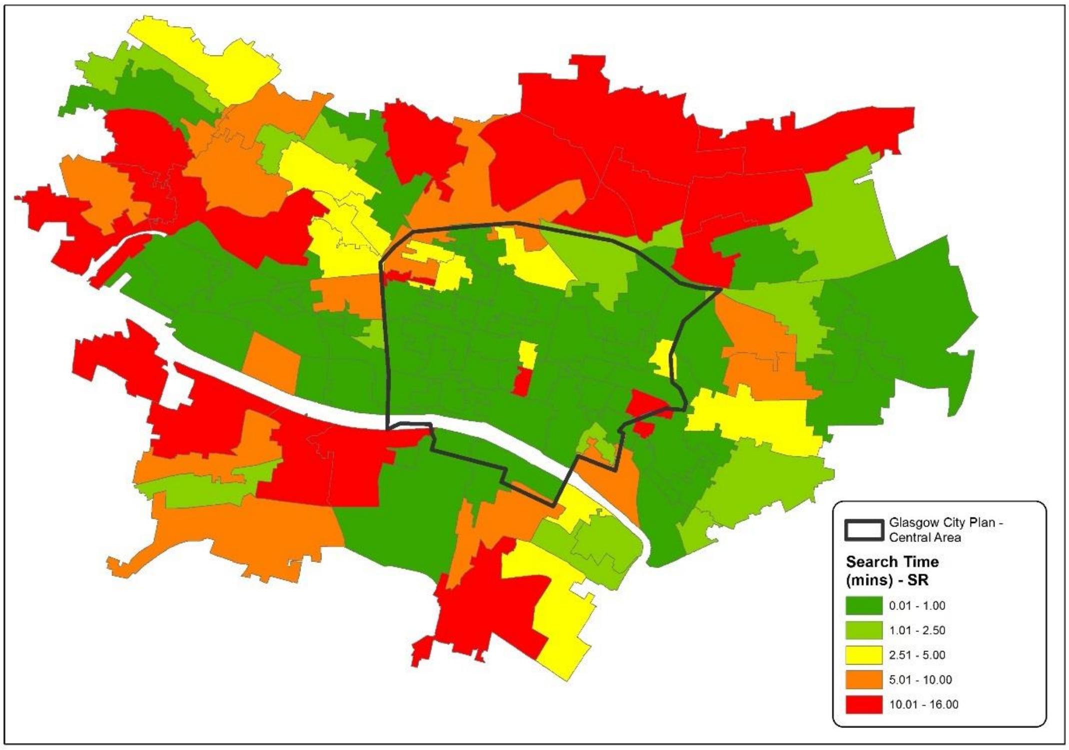


Figure 43. **Search Time – PM**

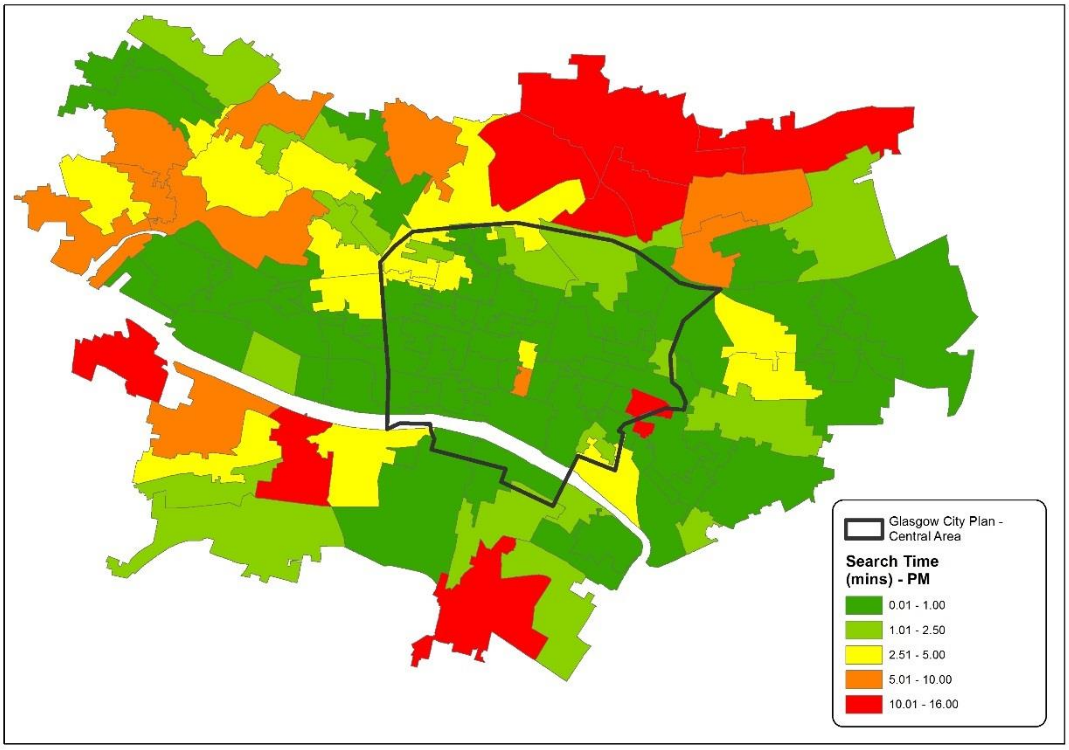


Table 42. Demand Model Summary – Mode Shares – Post inclusion of Parking Search Time

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
Employer's Business	81.8%	9.8%	0.0%	8.2%	0.2%	100.0%	88.6%	5.3%	0.0%	6.1%	0.0%	100.0%
Commute Car Available	73.2%	20.1%	0.0%	5.6%	1.1%	100.0%	78.9%	14.6%	0.0%	5.8%	0.7%	100.0%
Commute No Car Available	0.0%	67.9%	0.0%	29.0%	3.1%	100.0%	0.0%	65.9%	0.0%	30.6%	3.5%	100.0%
Other Car Available	79.1%	3.4%	0.0%	16.5%	1.0%	100.0%	82.7%	3.6%	0.0%	13.5%	0.2%	100.0%
Other No Car Available	0.0%	29.0%	0.0%	66.6%	4.4%	100.0%	0.0%	31.0%	0.0%	67.4%	1.6%	100.0%
Education Car Available	25.8%	27.0%	0.0%	43.1%	4.1%	100.0%	26.9%	22.5%	0.0%	49.7%	0.9%	100.0%
Education No Car Available	0.0%	25.5%	0.0%	69.9%	4.6%	100.0%	0.0%	30.8%	0.0%	68.0%	1.3%	100.0%
Retired Car Available	77.8%	3.2%	0.0%	16.4%	2.6%	100.0%	84.5%	3.4%	0.0%	11.7%	0.4%	100.0%
Retired No Car Available	0.0%	43.4%	0.0%	52.7%	3.9%	100.0%	0.0%	46.4%	0.0%	53.1%	0.4%	100.0%
Non Home Based Employer's Business	69.3%	23.2%	0.0%	7.4%	0.0%	100.0%	66.5%	22.2%	0.0%	11.4%	0.0%	100.0%
Non Home Based Other Car Available	43.0%	23.8%	0.0%	32.8%	0.4%	100.0%	51.9%	22.9%	0.0%	24.9%	0.4%	100.0%
Non Home Based Other No Car Available	0.0%	37.2%	0.0%	62.6%	0.2%	100.0%	0.0%	45.1%	0.0%	54.3%	0.5%	100.0%

*Run Name: Costs sourced from **BY_P2D** – Default Lambda Parameters (**Table 37**) – Output Spreadsheet:* **20170310_Full_MDC_Summary_1 0.xlsx**

Table 43. Demand Model Summary – Average Generalised Cost– Post inclusion of Parking Search Time

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
Employer's Business	26.2	313.3	0.0	53.9	0.0	0.0	25.0	105.0	9,999.0	54.4	24.9	0.0
Commute Car Available	26.6	131.1	0.0	66.8	41.6	0.0	25.7	120.2	9,999.0	81.0	42.4	0.0
Commute No Car Available	0.0	115.2	0.0	63.5	37.9	0.0	20.4	121.6	9,999.0	61.6	39.6	0.0
Other Car Available	15.1	129.9	0.0	51.2	48.0	0.0	14.4	94.1	9,999.0	53.4	47.6	0.0
Other No Car Available	0.0	117.9	0.0	48.6	46.3	0.0	15.3	94.2	9,999.0	45.8	45.4	0.0
Education Car Available	6.3	77.5	0.0	73.8	46.6	0.0	13.3	91.6	9,999.0	73.2	47.3	0.0
Education No Car Available	0.0	77.5	0.0	73.8	46.6	0.0	15.0	89.1	9,999.0	70.1	46.7	0.0
Retired Car Available	15.2	86.7	0.0	55.8	40.1	0.0	14.7	73.2	9,999.0	57.3	39.4	0.0
Retired No Car Available	0.0	84.1	0.0	50.7	51.7	0.0	15.3	67.2	9,999.0	45.3	50.8	0.0
Non Home Based Employer's Business	26.4	96.1	0.0	31.8	0.0	0.0	22.9	89.4	9,999.0	31.8	22.1	0.0
Non Home Based Other Car Available	15.7	135.5	0.0	50.2	32.2	0.0	15.6	115.9	9,999.0	51.0	35.4	0.0
Non Home Based Other No Car Available	0.0	138.9	0.0	51.9	30.3	0.0	17.6	109.6	9,999.0	53.7	34.8	0.0

*Run Name: Costs sourced from **BY_P2D** – Default Lambda Parameters (**Table 37**) – Output Spreadsheet:* **20170310_Full_MDC_Summary_1 0.xlsx**

11.2.23 The next stage was the inclusion of Park & Ride and re-adjusting the K factors as all the different parking models had now been incorporated within the demand model.

11.2.24 The updated Park and Ride parameters, alpha and mode constants are as indicated below.

Table 44. Adjusted Lambda Parameters (PnR Parameter Calibration)

DS	DEMAND SEGMENT	PARAMETER: LAMBDA PARAMETERS					
		MODE	CAR	PUT	PNR	WLK	CYC
1	Employer's Business	0.79	-0.067	-0.036	-0.030	-0.065	-0.067
2	Commute Car Available	0.81	-0.061	-0.030	-0.028	-0.055	-0.065
3	Commute No Car Available	0.68	-0.065	-0.033	-0.033	-0.063	-0.071
4	Other Car Available	0.78	-0.120	-0.043	-0.038	-0.090	-0.090
5	Other No Car Available	0.54	-0.090	-0.044	-0.036	-0.090	-0.090
6	Education Car Available	0.57	-0.179	-0.045	-0.036	-0.079	-0.090
7	Education No Car Available	0.56	-0.087	-0.043	-0.036	-0.073	-0.090
8	Retired Car Available	0.85	-0.120	-0.041	-0.030	-0.090	-0.090
9	Retired No Car Available	0.53	-0.090	-0.048	-0.036	-0.090	-0.090
10	Non Home Based Employer's Business	0.80	-0.081	-0.042	-0.037	-0.073	-0.081
11	Non Home Based Other Car Available	0.97	-0.100	-0.033	-0.028	-0.077	-0.077
12	Non Home Based Other No Car Available	0.81	-0.077	-0.033	-0.033	-0.077	-0.077

Table 45. Calibrated Demand Model- Alpha Parameters (PnR Parameter Calibration)

DS	DEMAND SEGMENT	PARAMETER: ALPHA – FACTOR COST CHANGE				
		CAR	PUT	PNR	WLK	CYC
1	Employer's Business	1.1	0.9	1.3	0.5	3.6
2	Commute Car Available	1.2	0.9	1.3	0.9	1.2
3	Commute No Car Available	1.5	1.0	1.0	1.1	1.4
4	Other Car Available	1.2	0.8	1.0	0.4	0.8
5	Other No Car Available	1.5	0.8	1.0	0.6	0.9
6	Education Car Available	1.8	1.2	1.0	1.3	0.8
7	Education No Car Available	1.0	1.1	1.0	0.7	0.8
8	Retired Car Available	1.2	1.0	1.3	0.4	0.7
9	Retired No Car Available	1.5	1.0	1.0	0.5	0.8
10	Non Home Based Employer's Business	0.9	0.9	1.3	0.9	1.8
11	Non Home Based Other Car Available	1.3	0.9	1.6	0.5	1.6
12	Non Home Based Other No Car Available	1.5	1.0	1.0	0.5	1.8

Units: Factor applied to model costs

Table 46. Calibrated Demand Model- ASC Parameters (PnR Parameter Calibration)

DS	DEMAND SEGMENT	PARAMETER: ASC – ABSOLUTE COST CHANGE				
		CAR	PUT	PNR	WLK	CYC
1	Employer's Business	-30.0	-1.4	53.0	-30.2	-15.8
2	Commute Car Available	-22.0	-14.6	54.0	-38.4	0.5
3	Commute No Car Available	0.0	35.3	0.0	-13.7	15.6
4	Other Car Available	-23.0	1.2	54.0	-26.4	10.6
5	Other No Car Available	0.0	22.5	0.0	-20.0	22.5
6	Education Car Available	17.7	8.6	0.0	-48.7	16.4
7	Education No Car Available	0.0	20.4	0.0	-21.7	25.9
8	Retired Car Available	-25.0	-2.6	55.0	-28.6	5.8
9	Retired No Car Available	0.0	5.0	0.0	-10.0	25.0
10	Non Home Based Employer's Business	5.0	-7.6	0.0	-30.2	5.4
11	Non Home Based Other Car Available	0.0	5.0	0.0	-21.0	2.5
12	Non Home Based Other No Car Available	0.0	20.5	0.0	-13.9	10.8

Units: Generalised Minutes

Table 47. Calibrated Demand Model- IZM Parameters (PnR Parameter Calibration)

DS	DEMAND SEGMENT	PARAMETER: INTRAZONAL MATRIX COST CHANGE				
		CAR	PUT	PNR	WLK	CYC
1	Employer's Business	-30.0	-27.0	30.0	-16.2	30.0
2	Commute Car Available	-4.7	19.7	30.0	-2.9	-11.8
3	Commute No Car Available	12.2	21.5	30.0	12.7	-2.8
4	Other Car Available	-7.8	9.0	30.0	-13.5	30.0
5	Other No Car Available	14.5	10.6	30.0	-6.8	0.8
6	Education Car Available	-24.0	-30.0	30.0	5.7	-6.8
7	Education No Car Available	14.0	-30.0	30.0	0.9	-9.9
8	Retired Car Available	-5.0	-4.7	30.0	-13.3	-30.0
9	Retired No Car Available	14.5	-4.9	30.0	-9.2	30.0
10	Non Home Based Employer's Business	-20.7	-23.2	30.0	9.6	30.0
11	Non Home Based Other Car Available	-9.3	-5.0	30.0	-7.8	6.2
12	Non Home Based Other No Car Available	12.9	-22.4	30.0	-8.5	30.0

Units: Generalised Minutes

11.2.25 The demand model was run with these parameters with the Park and Ride module switched on. The two tables below report the mode share and generalised cost distribution results.

Table 48. Demand Model Summary – Mode Shares – Post inclusion of Park and Ride

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
Employer's Business	88.3%	4.7%	1.4%	5.7%	0.0%	100.0%	88.6%	5.3%	0.0%	6.1%	0.0%	100.0%
Commute Car Available	78.0%	14.3%	2.4%	5.0%	0.3%	100.0%	78.9%	14.6%	0.0%	5.8%	0.7%	100.0%
Commute No Car Available	0.0%	67.8%	0.0%	29.5%	2.6%	100.0%	0.0%	65.9%	0.0%	30.6%	3.5%	100.0%
Other Car Available	81.8%	3.4%	1.2%	13.4%	0.2%	100.0%	82.7%	3.6%	0.0%	13.5%	0.2%	100.0%
Other No Car Available	0.0%	32.8%	0.0%	64.8%	2.4%	100.0%	0.0%	31.0%	0.0%	67.4%	1.6%	100.0%
Education Car Available	27.0%	23.6%	0.0%	46.4%	3.0%	100.0%	26.9%	22.5%	0.0%	49.7%	0.9%	100.0%
Education No Car Available	0.0%	33.3%	0.0%	63.9%	2.8%	100.0%	0.0%	30.8%	0.0%	68.0%	1.3%	100.0%
Retired Car Available	83.8%	3.1%	1.6%	11.1%	0.3%	100.0%	84.5%	3.4%	0.0%	11.7%	0.4%	100.0%
Retired No Car Available	0.0%	51.5%	0.0%	46.2%	2.3%	100.0%	0.0%	46.4%	0.0%	53.1%	0.4%	100.0%
Non Home Based Employer's Business	65.7%	24.0%	0.0%	10.1%	0.2%	100.0%	66.5%	22.2%	0.0%	11.4%	0.0%	100.0%
Non Home Based Other Car Available	51.0%	25.7%	0.0%	23.2%	0.2%	100.0%	51.9%	22.9%	0.0%	24.9%	0.4%	100.0%
Non Home Based Other No Car Available	0.0%	47.4%	0.0%	52.3%	0.3%	100.0%	0.0%	45.1%	0.0%	54.3%	0.5%	100.0%

*Run Name: Costs sourced from **BY_P2E** – Default Lambda Parameters (**Table 37**) – Output Spreadsheet:* **20170417_Full_MDC_Summary_2 3.xlsx**

Table 49. Demand Model Summary – Average Generalised Cost– Post inclusion of Park and Ride

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
Employer's Business	25.9	130.2	0.0	53.9	0.0	0.0	25.0	100.9	91.7	54.0	24.1	0.0
Commute Car Available	26.3	128.6	0.0	66.8	41.6	0.0	26.8	125.6	103.4	76.0	40.7	0.0
Commute No Car Available	0.0	114.0	0.0	63.4	37.8	0.0	20.5	115.9	116.2	64.4	38.1	0.0
Other Car Available	14.9	116.7	0.0	51.1	48.0	0.0	14.8	104.8	98.7	51.9	46.9	0.0
Other No Car Available	0.0	110.1	0.0	48.5	46.3	0.0	15.5	102.8	113.1	45.7	45.4	0.0
Education Car Available	6.3	78.8	0.0	73.8	46.6	0.0	7.6	74.1	9,999.0	76.6	45.7	0.0
Education No Car Available	0.0	78.8	0.0	73.8	46.6	0.0	22.1	75.7	9,999.0	76.5	44.0	0.0
Retired Car Available	15.0	87.5	0.0	55.8	40.1	0.0	15.0	86.0	87.7	54.5	38.3	0.0
Retired No Car Available	0.0	83.9	0.0	50.7	51.7	0.0	15.5	78.2	102.3	46.4	50.6	0.0
Non Home Based Employer's Business	25.8	95.9	0.0	31.8	0.0	0.0	23.6	86.8	153.6	33.6	27.9	0.0
Non Home Based Other Car Available	15.5	110.3	0.0	50.2	32.2	0.0	15.9	112.7	169.2	47.7	34.8	0.0
Non Home Based Other No Car Available	0.0	105.3	0.0	51.9	30.3	0.0	17.8	103.7	162.2	50.9	34.8	0.0

Run Name: Costs sourced from ***BY_P2E*** *– Default Lambda Parameters (****Table 37****) – Output Spreadsheet:* **20170417_Full_MDC_Summary_2 3.xlsx**

11.2.26 The results above were reviewed and deemed a sufficient match to generate matrices for the assignment models.

11.2.27 The assignment matrices were passed to the assignment model and used as the basis of the calibration and matrix estimation for Phase 2.

11.3 Final Demand Model Calibration

11.3.1 The demand matrices produced by the matrix estimation were then used to derive a new set of demand model costs for each of the modes.

11.3.2 These costs were then input into the demand model, with the demand model calibration statistics output for checking. A series of checks listed below have been performed on the output with a subsequent section of text detailing the checks:

- Trip End check;
- Journey Purpose check / breakdown compared with Mobile Phone Data;
- Mode Share checks;
- Generalised Cost Distribution check;
- Trip Length Distribution check;
- Elasticity (indicative check)
- Incremental Adjustment; and
- Phase 1 elasticity checks.

11.4 Trip End Check

11.4.1 The checks performed on the trip end model were:

- Total Number of Trips versus Population check;
- Journey Purpose / Demand Segment Proportion check;
- Traveller Type check compared with equivalent mobile phone data; and
- Plots of output trip ends, by demand segment (total presented in report).

11.4.2 The table below provides an analysis of the 24-hour production and attraction totals and the corresponding per person trip rates.

11.4.3 In general, the expectation would be for between 2.5 and 3 trips per person for productions. The results for all local authorities are within this range with the exception of Argyll and Bute, which could be distorted by being only partially included within the model.

Table 50. Trip End versus Population Check

#	LOCAL AUTHORITY	POPN	PRODUCTIONS		ATTRACTIONS	
			HB RATE	NHB RATE	HB RATE	NHB RATE
1	South Lanarkshire	315360	2.54	0.27	2.17	0.29
2	East Ayrshire	122149	2.52	0.29	2.18	0.25
3	South Ayrshire	112510	2.52	0.34	2.57	0.34
4	North Ayrshire	131861	2.45	0.24	1.93	0.25
5	East Renfrewshire	92380	2.44	0.16	1.37	0.13
6	Glasgow City North	355455	2.64	0.38	2.98	0.36
7	Glasgow City South	238718	2.38	0.32	2.47	0.29
8	Glasgow City Centre	5376	16.05	12.53	90.47	16.07
9	North Lanarkshire	337950	2.56	0.29	2.28	0.29
10	East Dunbartonshire	106730	2.46	0.21	1.71	0.19
11	Renfrewshire	174230	2.58	0.34	2.64	0.37
12	Inverclyde	88875	2.26	0.27	2.12	0.23
13	West Dunbartonshire	89729	2.53	0.28	2.29	0.27
14	Argyll and Bute	17149	3.76	0.33	2.23	0.26
ALL		2188473	2.56	0.33	2.56	0.33

Note: PA format

11.4.4 As expected, the number of trips produced by and attracted to Glasgow City Centre is much higher than elsewhere due to the inclusion of non-home-based trips within the total productions and total attractions.

11.5 Mode Share Analysis

11.5.1 The results of the final model in terms of mode share are presented in Table 51 and Figure 44 below.

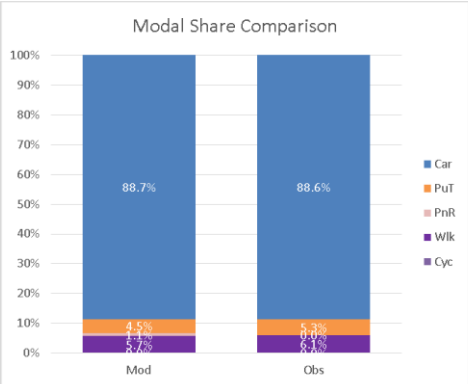
Table 51. Demand Model Summary – Mode Shares

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
Employer's Business	88.7%	4.5%	1.1%	5.7%	0.0%	100.0%	88.6%	5.3%	0.0%	6.1%	0.0%	100.0%
Commute Car Available	78.8%	14.1%	1.9%	5.0%	0.3%	100.0%	78.9%	14.6%	0.0%	5.8%	0.7%	100.0%
Commute No Car Available	0.0%	67.3%	0.0%	30.2%	2.5%	100.0%	0.0%	65.9%	0.0%	30.6%	3.5%	100.0%
Other Car Available	82.2%	3.3%	1.2%	13.2%	0.2%	100.0%	82.7%	3.6%	0.0%	13.5%	0.2%	100.0%
Other No Car Available	0.0%	32.4%	0.0%	65.2%	2.3%	100.0%	0.0%	31.0%	0.0%	67.4%	1.6%	100.0%
Education Car Available	26.2%	22.2%	0.0%	50.2%	1.4%	100.0%	26.9%	22.5%	0.0%	49.7%	0.9%	100.0%
Education No Car Available	0.0%	33.3%	0.0%	63.9%	2.8%	100.0%	0.0%	30.8%	0.0%	68.0%	1.3%	100.0%
Retired Car Available	84.0%	3.1%	1.5%	11.2%	0.3%	100.0%	84.5%	3.4%	0.0%	11.7%	0.4%	100.0%
Retired No Car Available	0.0%	47.3%	0.0%	50.6%	2.1%	100.0%	0.0%	46.4%	0.0%	53.1%	0.4%	100.0%
Non Home Based Employer's Business	66.5%	23.3%	0.0%	10.1%	0.2%	100.0%	66.5%	22.2%	0.0%	11.4%	0.0%	100.0%
Non Home Based Other Car Available	51.5%	25.0%	0.0%	23.4%	0.2%	100.0%	51.9%	22.9%	0.0%	24.9%	0.4%	100.0%
Non Home Based Other No Car Available	0.0%	44.6%	0.0%	55.2%	0.3%	100.0%	0.0%	45.1%	0.0%	54.3%	0.5%	100.0%

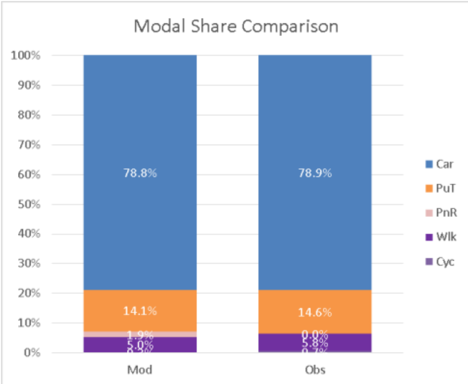
*Run Name: Costs sourced from **BYP2H**– Default Lambda Parameters (**Table 37**) – Output Spreadsheet:* **20150503_Full_MDC_Summary_3 4.xlsx**

Figure 44. **Demand Model Summary – Mode Share Charts**

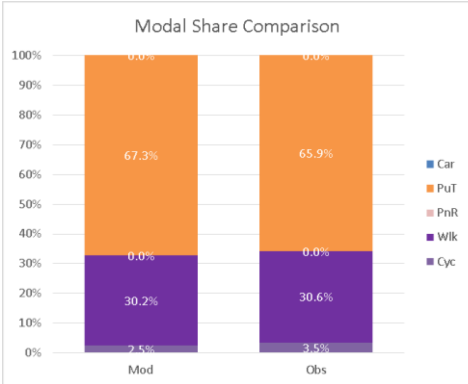
DS1 – Employer's Business



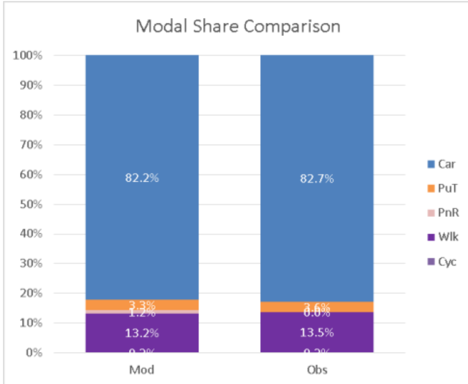
DS2 – Commute Car Available



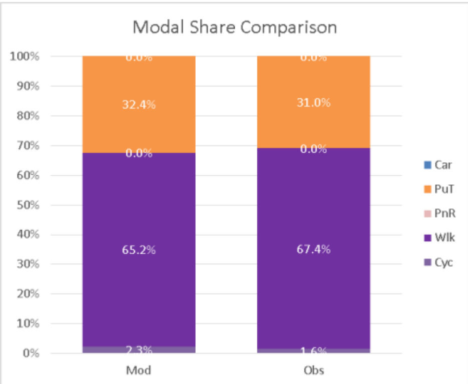
DS3 – Commute No Car Available



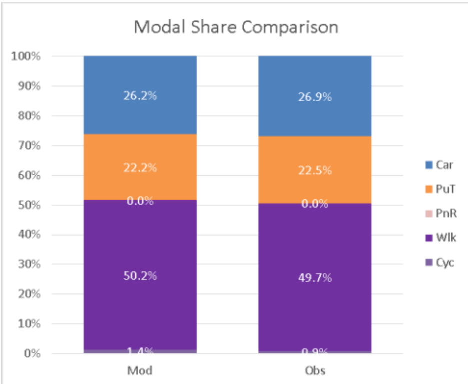
DS4 - Other Car Available



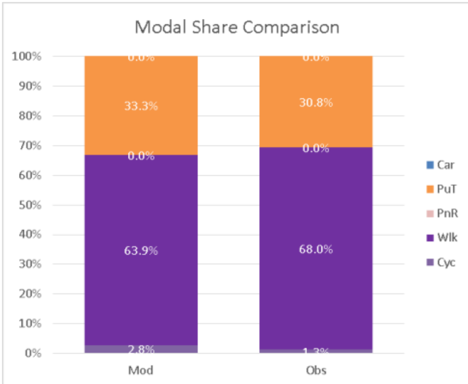
DS5 - Other No Car Available



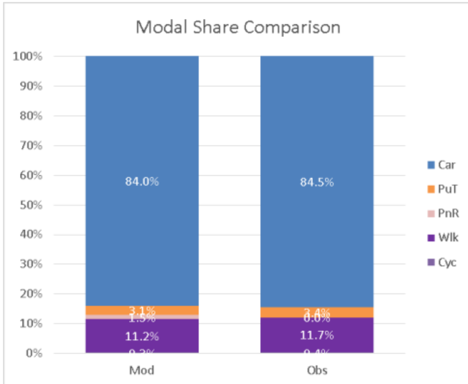
DS6 – Education Car Available



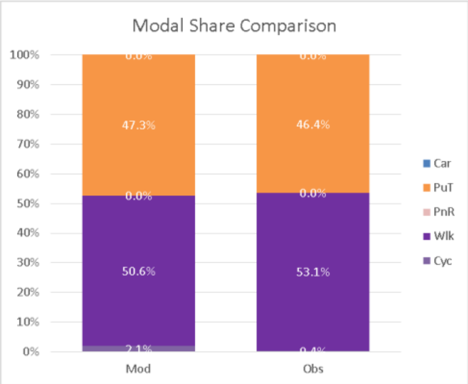
DS7 – Education No Car Available

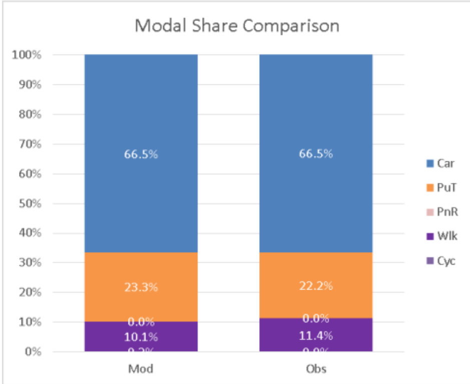


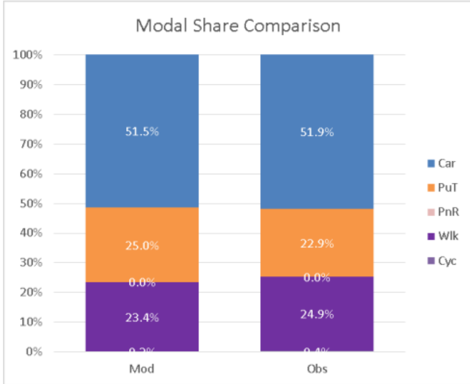
DS8 – Retired Car Available

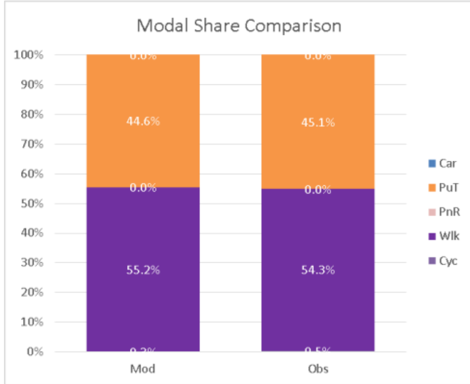


DS9 – Retired No Car Available	DS10 – NHB Employers Business	DS11 – NHB Others Car Available	DS12 – NHB Others No Car Available









Run Name: Costs sourced from ***BYP2H****– Default Lambda Parameters (****Table 37****) – Output Spreadsheet:* **20170503_Full_MDC_Summary_3 4.xlsx**

11.5.2 The mode shares are a good representation of the observed data. For car-available travellers, the mode share for car is generally slightly lower than observed, with the active modes correspondingly over-estimated.

11.5.3 For no-car-available trips there is a similar trend, with slightly lower than observed public transport share, offset by a greater walk / active share.

11.5.4 Overall though, the results show a good match between the modelled and observed data for mode shares.

11.6 Generalised Cost Distributions

11.6.1 The generalised cost distributions for the final demand model are provided in Table 52 and Figure 45 below.

11.6.2 The figures represent the aggregated 'all mode' trip cost distributions by demand segment. The mode-specific plots are available on request via the calibration spreadsheet.

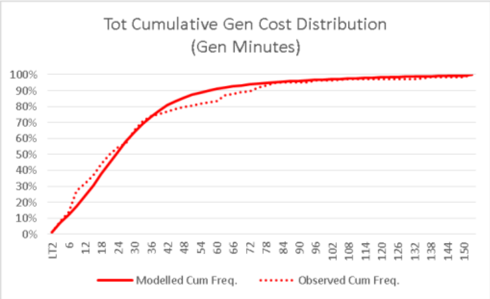
Table 52. Demand Model Summary – Average Generalised Cost

DEMAND SEGMENT	MODELLED						OBSERVED					
	CAR	PUT	PNR	WLK	CYC	TOTAL	CAR	PUT	PNR	WLK	CYC	TOTAL
Employer's Business	25.9	130.2	0.0	53.9	0.0	0.0	25.0	100.3	93.2	53.7	24.0	0.0
Commute Car Available	26.3	128.6	0.0	66.8	41.6	0.0	26.9	125.1	103.8	76.7	40.6	0.0
Commute No Car Available	0.0	114.0	0.0	63.4	37.8	0.0	20.5	116.0	232.9	64.3	38.1	0.0
Other Car Available	14.9	116.7	0.0	51.1	48.0	0.0	14.8	104.7	100.4	51.9	46.9	0.0
Other No Car Available	0.0	110.1	0.0	48.5	46.3	0.0	15.5	102.8	230.2	45.7	45.4	0.0
Education Car Available	6.3	78.8	0.0	73.8	46.6	0.0	7.6	73.8	9,999.0	76.3	46.8	0.0
Education No Car Available	0.0	78.8	0.0	73.8	46.6	0.0	22.1	75.7	9,999.0	76.5	44.0	0.0
Retired Car Available	15.0	87.5	0.0	55.8	40.1	0.0	15.0	86.0	90.1	54.4	38.3	0.0
Retired No Car Available	0.0	83.9	0.0	50.7	51.7	0.0	15.5	78.1	219.3	46.5	50.7	0.0
Non Home Based Employer's Business	25.8	95.9	0.0	31.8	0.0	0.0	23.6	86.7	272.2	33.6	27.9	0.0
Non Home Based Other Car Available	15.5	110.3	0.0	50.2	32.2	0.0	15.9	112.7	286.8	47.7	34.8	0.0
Non Home Based Other No Car Available	0.0	105.3	0.0	51.9	30.3	0.0	17.8	103.8	279.6	51.0	34.9	0.0

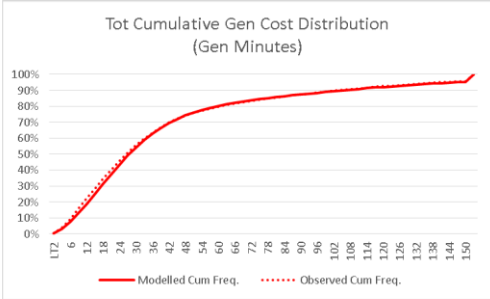
*Run Name: Costs sourced from **BYP2H**– Default Lambda Parameters (**Table 37**) – Output Spreadsheet:* **20170503_Full_MDC_Summary_3 4.xlsx**

Figure 45. **Demand Model Summary – Cumulative Generalised Cost Charts)**

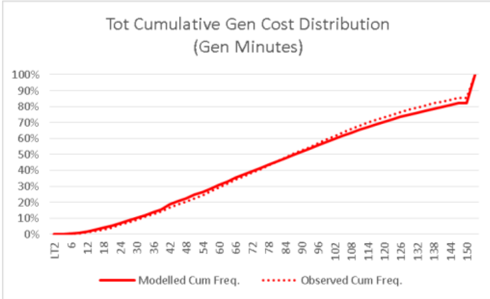
DS1 – Employer's Business



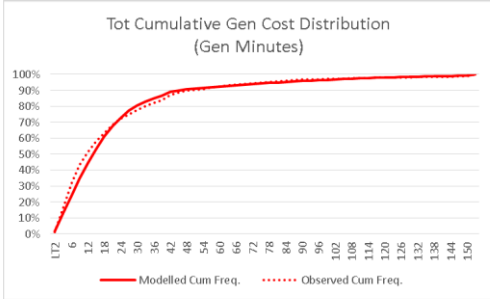
DS2 – Commute Car Available



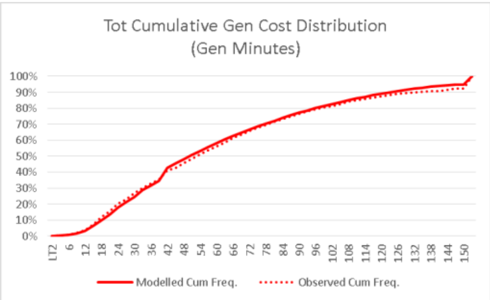
DS3 – Commute No Car Available



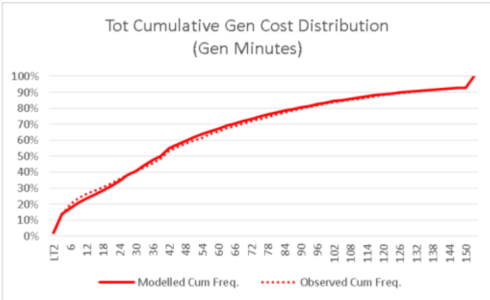
DS4 - Other Car Available



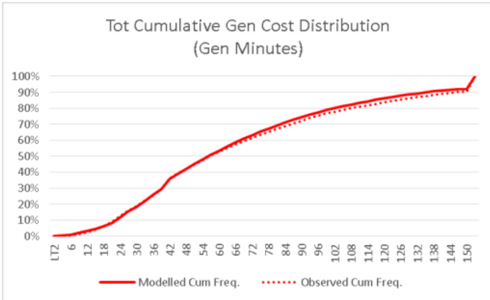
DS5 - Other No Car Available



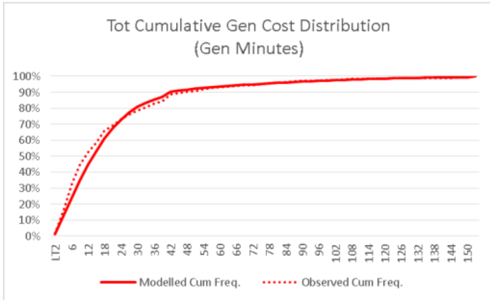
DS6 – Education Car Available



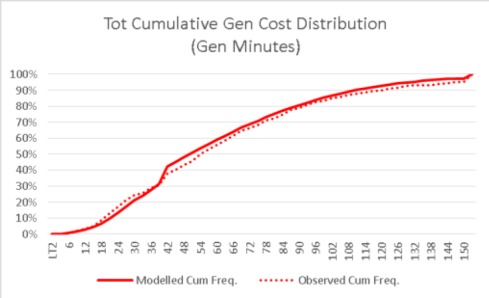
DS7 – Education No Car Available

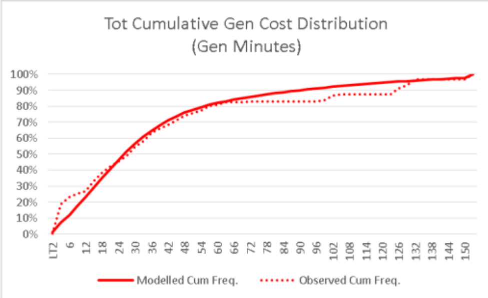


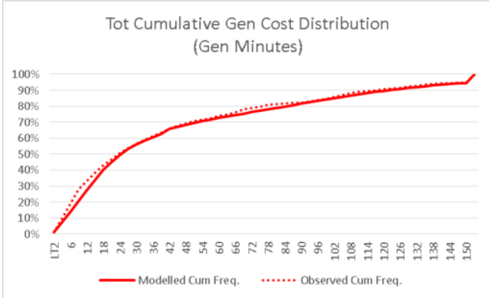
DS8 – Retired Car Available

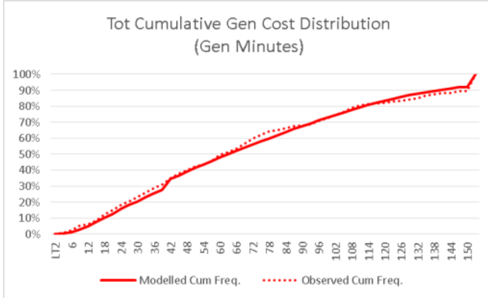


DS9 – Retired No Car Available	DS10 – NHB Employers Business	DS11 – NHB Others Car Available	DS12 – NHB Others No Car Available









Run Name: Costs sourced from ***BYP2H****– Default Lambda Parameters (****Table 37****) – Output Spreadsheet:* **20170503_Full_MDC_Summary_3 4.xlsx**

11.6.3 The cumulative “all-trips” generalised cost distributions show a good fit with the observed data.

11.6.4 As expected, the results are poorer for the Employers’ Business demand segments, this is primarily as a consequence of fewer data records for these demand segments resulting in a less smooth trip cost distribution.

11.7 Trip Length Distributions

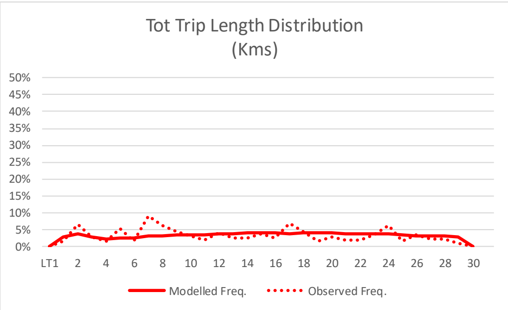
11.7.1 The generalised length distributions for the final demand model are illustrated below.

All mode trip length distributions

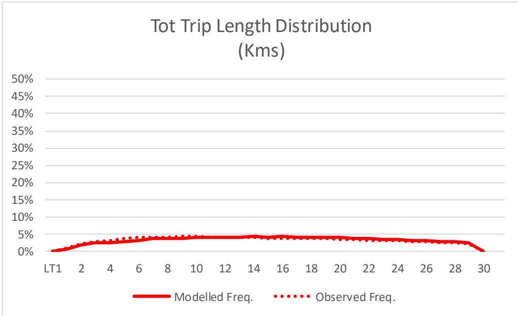
11.7.2 Figure 46 represents the aggregated ‘all mode’ trip length distributions by demand segment.

Figure 46. **Demand Model Summary – 'all mode' Trip Length Distribution Charts**

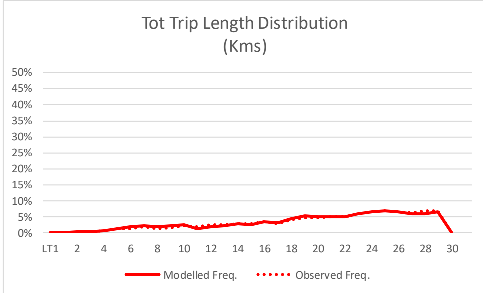
DS1 – Employer's Business



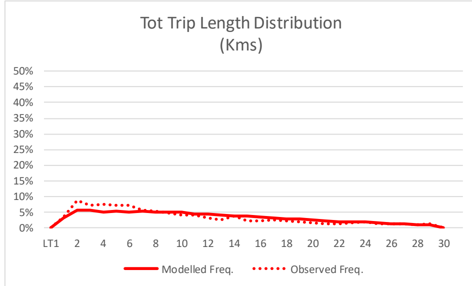
DS2 – Commute Car Available



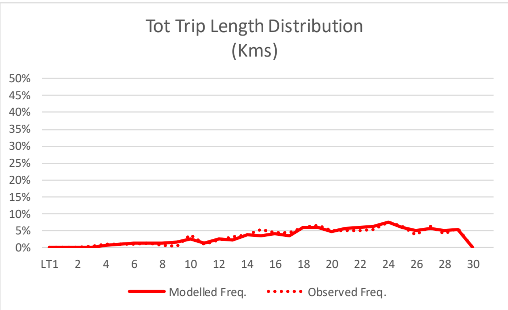
DS3 – Commute No Car Available



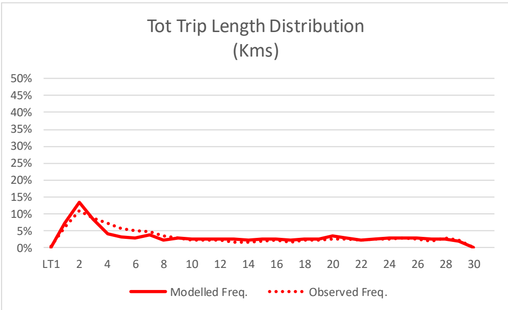
DS4 - Other Car Available



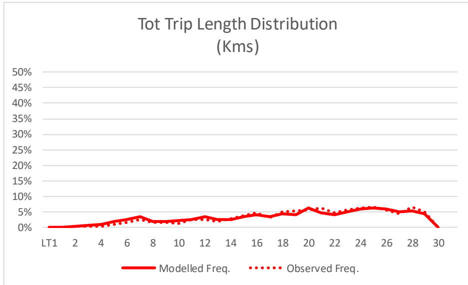
DS5 - Other No Car Available



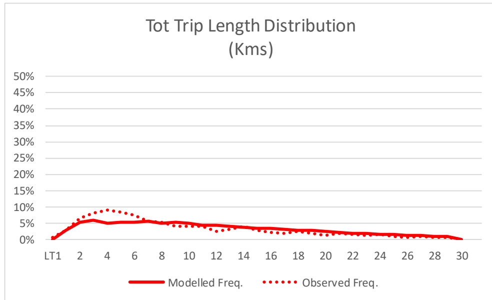
DS6 – Education Car Available

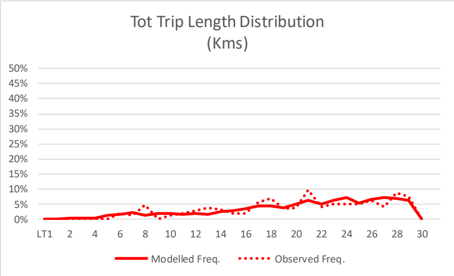
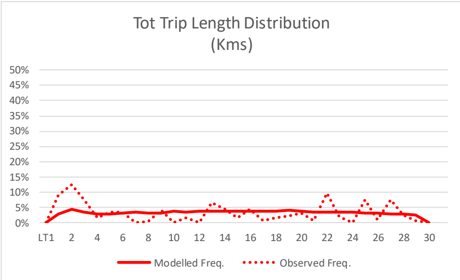
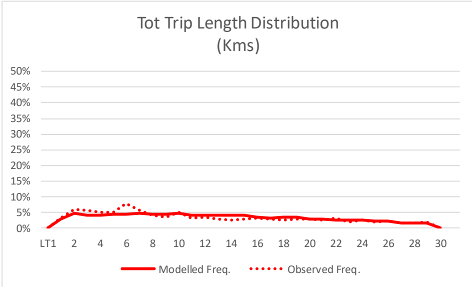
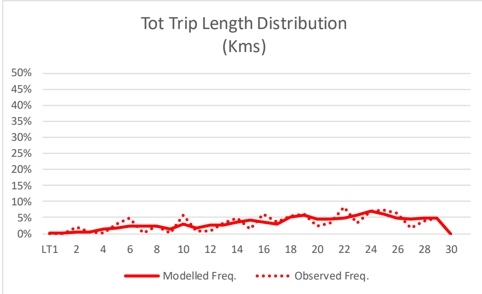


DS7 – Education No Car Available



DS8 – Retired Car Available



DS9 – Retired No Car Available	DS10 – NHB Employers Business	DS11 – NHB Others Car Available	DS12 – NHB Others No Car Available
			

Run Name: Costs sourced from BYP2H– Default Lambda Parameters (Table 37) – Output Spreadsheet: 20170503_Full_MDC_Summary_non_Cumulative_TL_3 4.xlsx

11.7.3 The “all trips” trip length distributions show a good fit with the observed data.

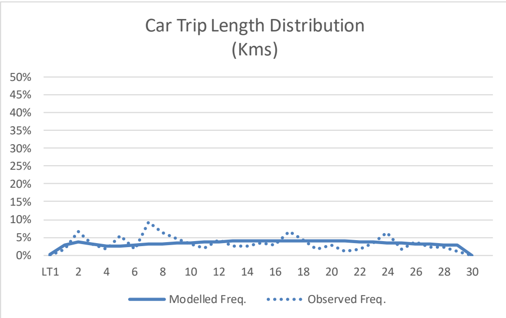
11.7.4 The level of fit is lower for the Employers Business journey purpose, this is expected due to fewer data for calculation of the observed trip lengths.

Car trip length distributions

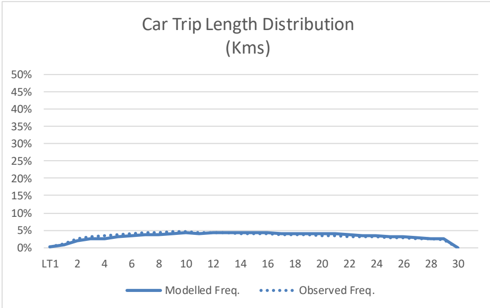
11.7.5 Figure 47 represents the aggregated car trip length distributions by demand segment.

Figure 47. **Demand Model Summary – Car Trip Length Distribution Charts**

DS1 – Employer’s Business



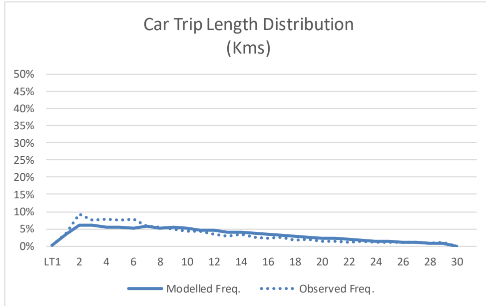
DS2 – Commute Car Available



DS3 – Commute No Car Available

N/A

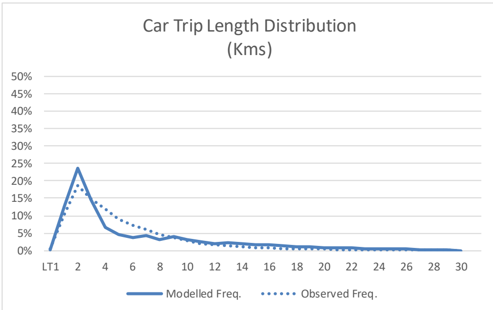
DS4 - Other Car Available



DS5 - Other No Car Available

N/A

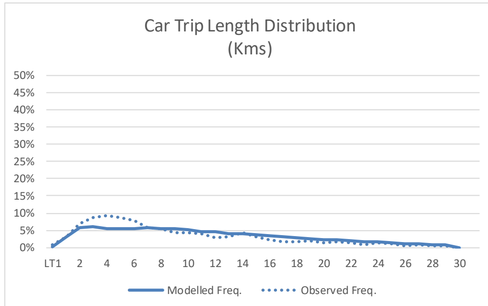
DS6 – Education Car Available

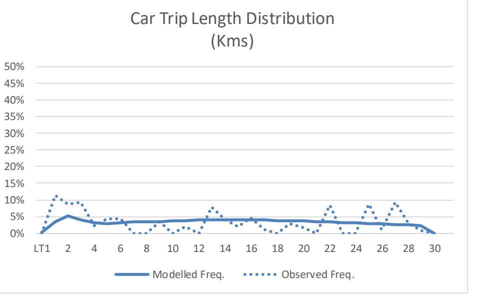
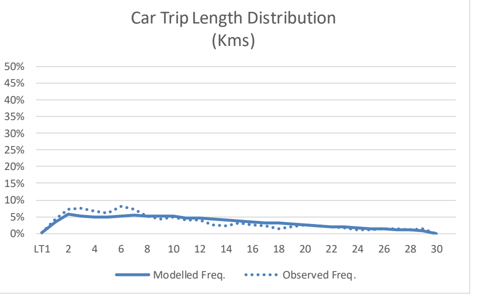


DS7 – Education No Car Available

N/A

DS8 – Retired Car Available



DS9 – Retired No Car Available	DS10 – NHB Employers Business	DS11 – NHB Others Car Available	DS12 – NHB Others No Car Available
N/A			N/A

Run Name: Costs sourced from BYP2H– Default Lambda Parameters (Table 37) – Output Spreadsheet: 20170503_Full_MDC_Summary_non_Cumulative_TL_3 4.xlsx

11.7.6 The car trip length distributions show a good fit with the observed data.

11.7.7 The level of fit is lower for the Employers Business journey purpose, this is expected due to fewer data for calculation of the observed trip lengths.

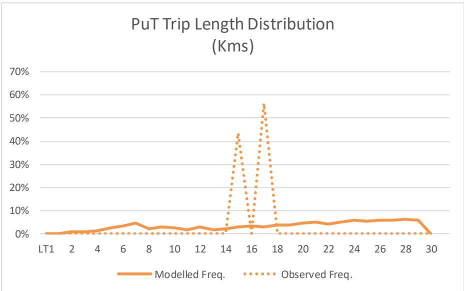
PT trip length distributions

11.7.8 Figure 48 represents the aggregated PT trip length distributions by demand segment.

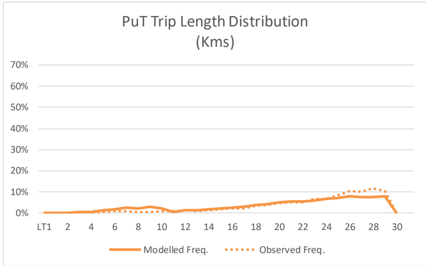
SYSTRA

Figure 48. **Demand Model Summary – PT Trip Length Distribution Charts**

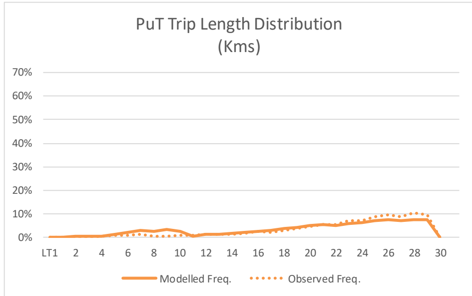
DS1 – Employer's Business



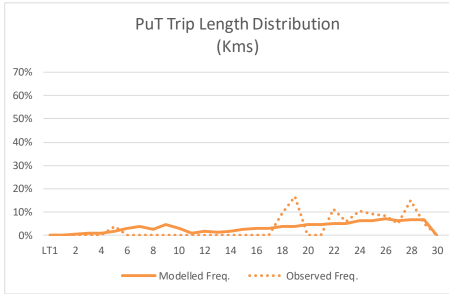
DS2 – Commute Car Available



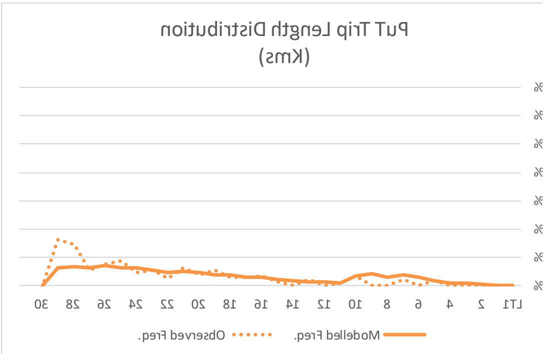
DS3 – Commute No Car Available



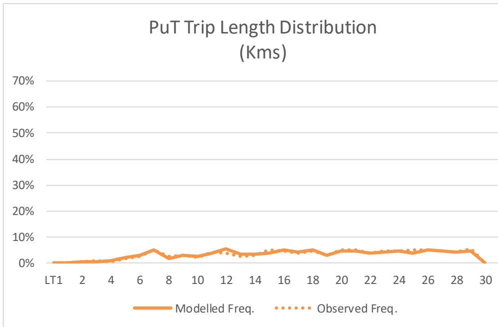
DS4 - Other Car Available



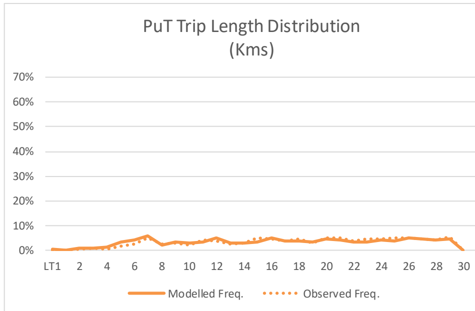
DS5 - Other No Car Available



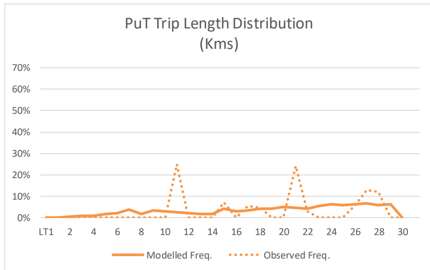
DS6 – Education Car Available



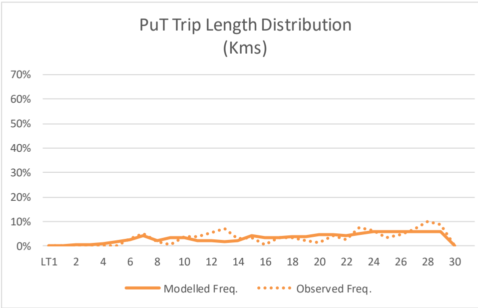
DS7 – Education No Car Available

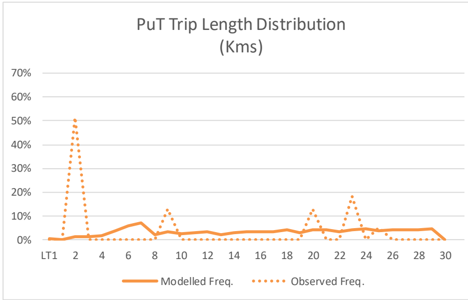


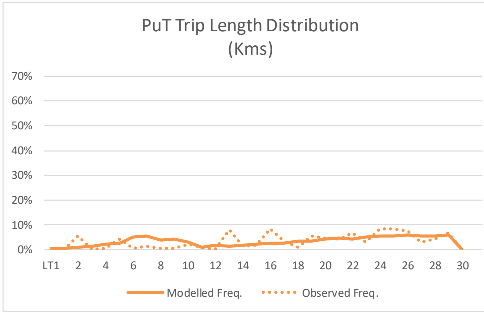
DS8 – Retired Car Available

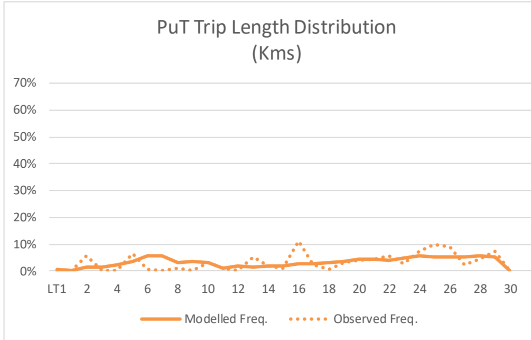


DS9 – Retired No Car Available	DS10 – NHB Employers Business	DS11 – NHB Others Car Available	DS12 – NHB Others No Car Available









Run Name: Costs sourced from BYP2H– Default Lambda Parameters (Table 37) – Output Spreadsheet: 20170503_Full_MDC_Summary_non_Cumulative_TL_3 4.xlsx

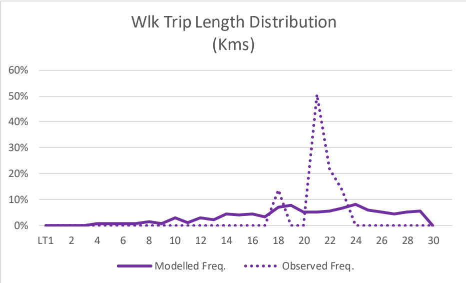
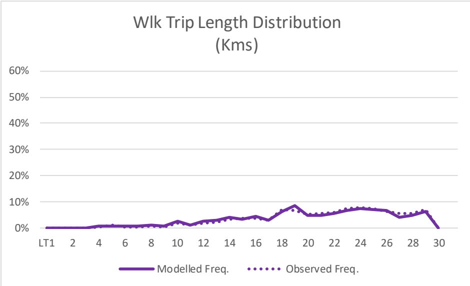
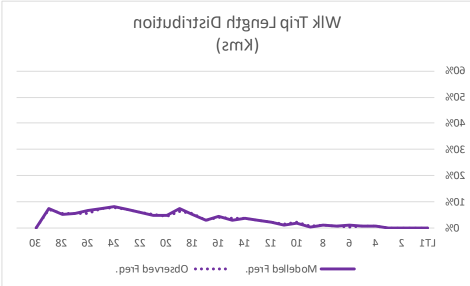
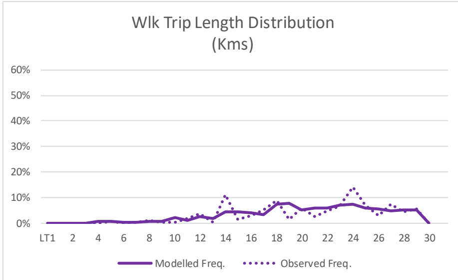
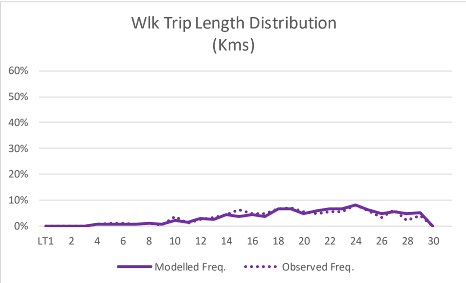
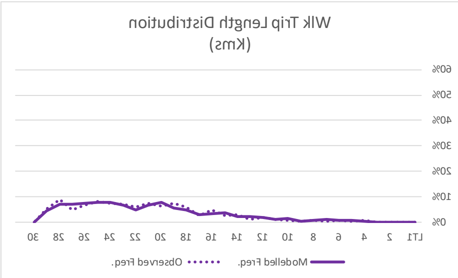
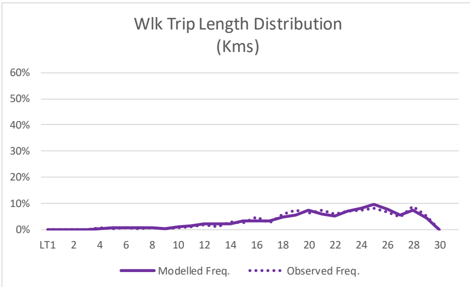
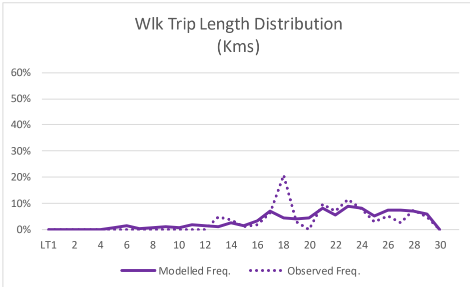
11.7.9 The PT trip length distributions show a good fit with the observed data.

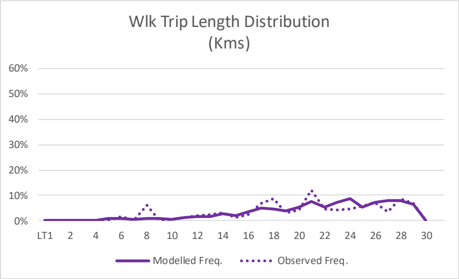
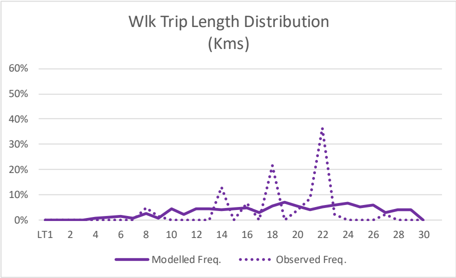
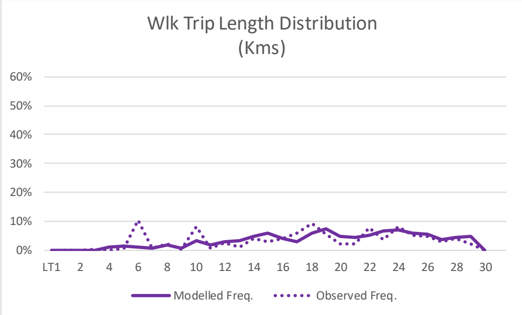
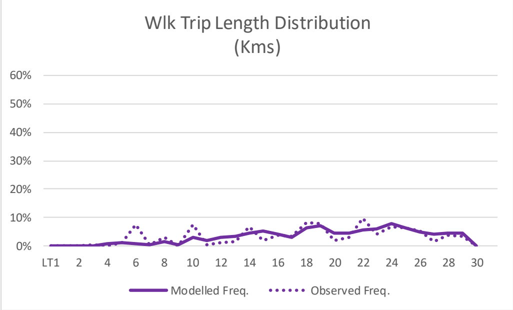
11.7.10 The level of fit is lower for the Employers Business journey purpose, this is expected due to fewer data for calculation of the observed trip lengths.

Walk trip length distributions

11.7.11 Figure 49 represents the aggregated walk trip length distributions by demand segment.

Figure 49. **Demand Model Summary – Walk Trip Length Distribution Charts**

DS1 – Employer's Business	DS2 – Commute Car Available	DS3 – Commute No Car Available	DS4 - Other Car Available
			
DS5 - Other No Car Available	**DS6 – Education Car Available**	**DS7 – Education No Car Available**	**DS8 – Retired Car Available**
			

DS9 – Retired No Car Available	DS10 – NHB Employers Business	DS11 – NHB Others Car Available	DS12 – NHB Others No Car Available
			

Run Name: Costs sourced from ***BYP2H****– Default Lambda Parameters (****Table 37****) – Output Spreadsheet:* **20170503_Full_MDC_Summary_non_Cumulative_TL_3 4.xlsx**

11.7.12 The walk trip length distributions show a good fit with the observed data.

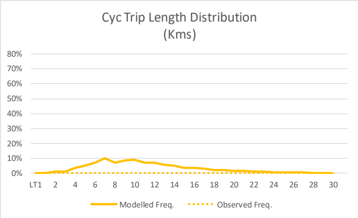
11.7.13 The level of fit is lower for the Employers Business journey purpose, this is expected due to fewer data for calculation of the observed trip lengths.

Cycle trip length distributions

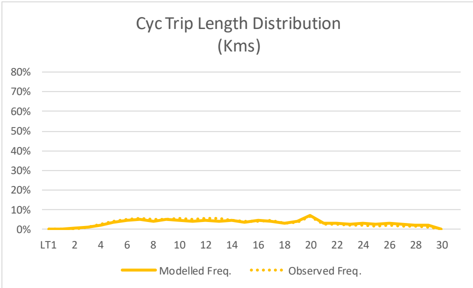
11.7.14 Figure 50 represents the aggregated cycle trip length distributions by demand segment.

Figure 50. **Demand Model Summary – Cycle Trip Length Distribution Charts**

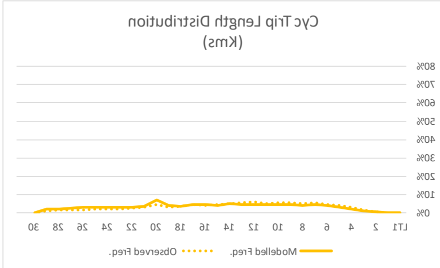
DS1 – Employer's Business



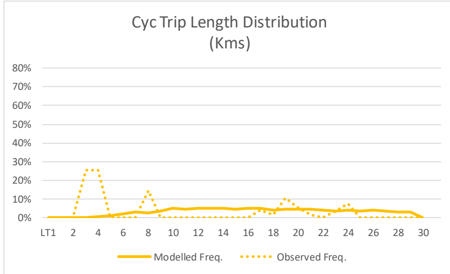
DS2 – Commute Car Available



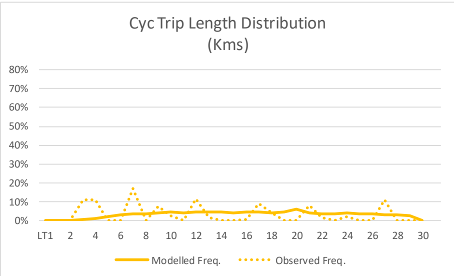
DS3 – Commute No Car Available



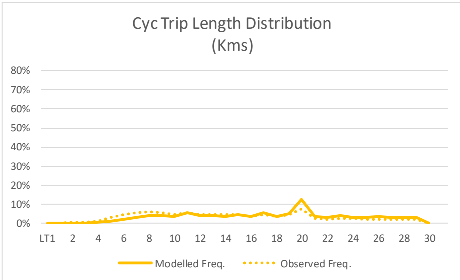
DS4 - Other Car Available



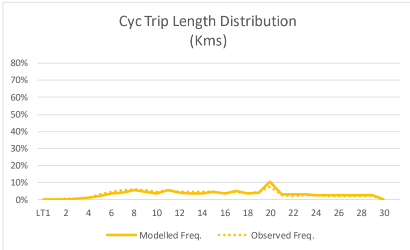
DS5 - Other No Car Available



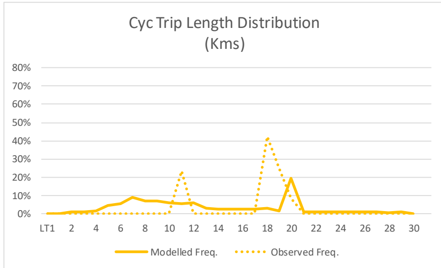
DS6 – Education Car Available



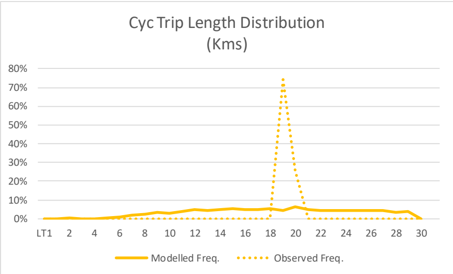
DS7 – Education No Car Available

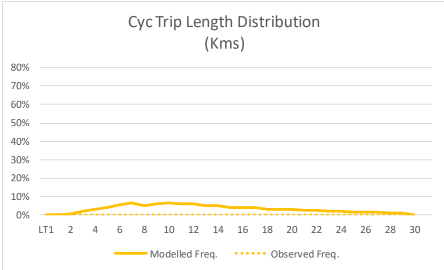


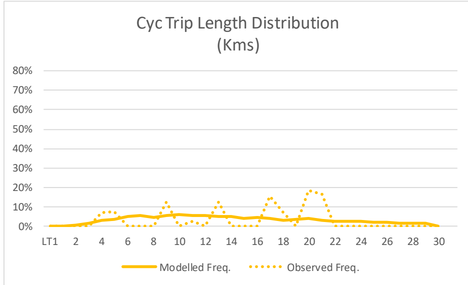
DS8 – Retired Car Available

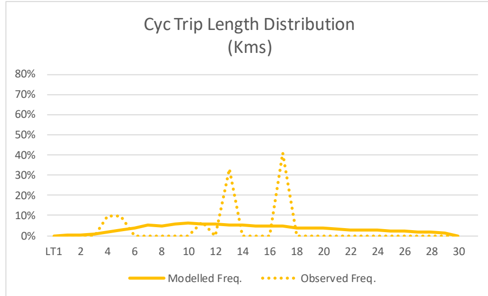


DS9 – Retired No Car Available	DS10 – NHB Employers Business	DS11 – NHB Others Car Available	DS12 – NHB Others No Car Available









*Run Name: Costs sourced from **BYP2H**– Default Lambda Parameters (**Table 37**) – Output Spreadsheet:* **20170503_Full_MDC_Summary_non_Cumulative_TL_3 4.xlsx**

11.7.15 The cycle trip length distributions show a good fit with the observed data and the level of fit is lower for retired and other journey purposes.

11.8 Sector Analysis Checks

11.8.1 The final demand model matrices have been compared with census and mobile phone data at the local authority level and "K factor" four sector level. This has been undertaken independently of model calibration as a validation check of the matrices. This can be made available upon request.

11.8.2 The census comparison at the 4 sector system is presented below, both in tabular and graphical format.

Table 53. Commuter Car trips – Model vs Census

SECTOR	SECTOR – CELLS SPLIT MODEL / CENSUS							
	1		2		3		TOTAL	
1 – Central	0.3%	0.0%	2.0%	2.6%	0.1%	0.2%	2.4%	2.8%
2 – Glasgow	3.5%	2.6%	75.6%	74.6%	2.1%	2.3%	81.2%	79.5%
3 – Rest	0.2%	0.2%	2.5%	2.3%	13.7%	15.2%	16.4%	17.7%
TOTAL	4.0%	2.8%	80.1%	79.5%	15.9%	17.7%	100.0%	100.0%

Table 54. Commuter Public Transport Trips– Model vs Census

SECTOR	SECTOR – CELLS SPLIT MODEL / CENSUS							
	1		2		3		TOTAL	
1 – Central	0.6%	0.1%	12.7%	19.0%	0.8%	1.3%	14.2%	20.4%
2 – Glasgow	13.8%	19.0%	60.2%	51.1%	1.3%	0.9%	75.3%	71.0%
3 – Rest	0.9%	1.3%	1.3%	0.9%	8.4%	6.4%	10.6%	8.6%
TOTAL	15.2%	20.4%	74.2%	71.0%	10.5%	8.6%	100.0%	100.0%

Figure 51. **Commuter Car trips – Model vs Census**

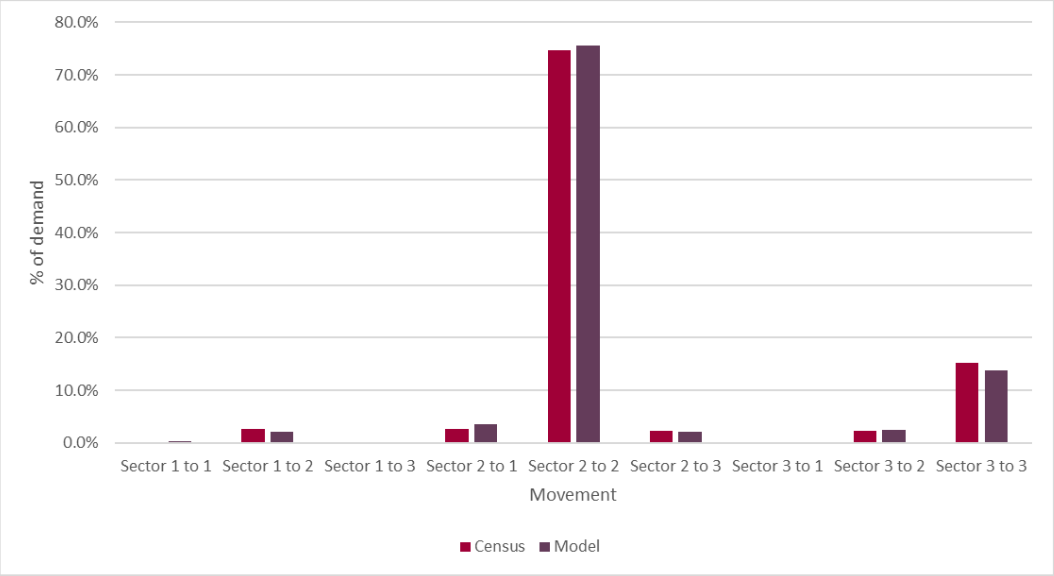
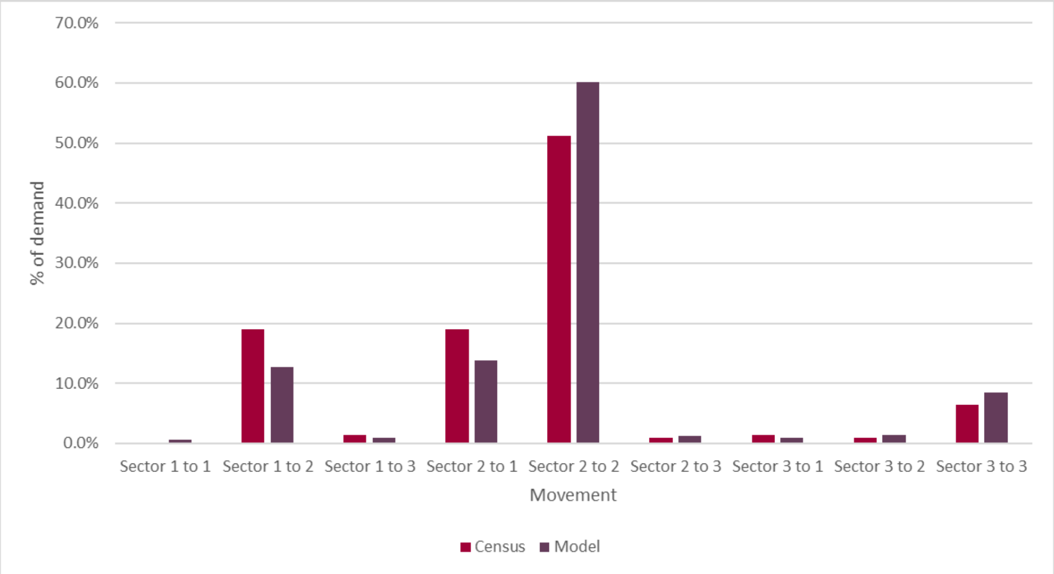


Figure 52. **Commuter Public Transport Trips– Model vs Census**



11.8.3 The census trips have been assumed to directly return for the purpose of this analysis and thus the pattern for the census data is symmetrical.

11.8.4 These tables illustrate a general close match between the sector-to-sector disaggregation, though the public transport pattern suggests the model is predicting more 'intra-sector' public transport trips in Sector 2, with correspondingly less of the model's public transport trips occurring between Sector 1 and Sector 2. This may be due to the costs of public transport being quite similar for movements to the city centre compared to adjacent zones in Glasgow. This effect occurs as the waiting time, access time and fare would be broadly consistent, but the journey time would be the main differential in public transport costs to a specific zone.

11.8.5 A similar comparison against the mobile phone data was undertaken, with the results at the four sector system displayed in the following four tables and corresponding graphs.

Table 55. Home-based Regular Destination – Model vs MPD

SECTOR	SECTOR – CELLS SPLIT MODEL / MPD							
	1		2		3		TOTAL	
1 – Central	0.5%	0.1%	5.3%	5.7%	0.3%	0.4%	6.0%	6.1%
2 – Glasgow	5.4%	5.8%	72.3%	73.3%	1.2%	1.7%	79.0%	80.8%
3 – Rest	0.3%	0.3%	1.2%	1.6%	13.5%	11.2%	15.0%	13.0%
TOTAL	6.2%	6.2%	78.8%	80.6%	15.0%	13.2%	100.0%	100.0%

Table 56. Home-based Others – Model vs MPD

SECTOR	SECTOR – CELLS SPLIT MODEL / MPD							
	1		2		3		TOTAL	
1 – Central	0.5%	0.1%	3.9%	3.1%	0.1%	0.1%	4.5%	3.3%
2 – Glasgow	4.1%	3.2%	74.2%	79.3%	0.6%	0.8%	78.8%	83.3%
3 – Rest	0.1%	0.1%	0.6%	0.8%	16.0%	12.5%	16.7%	13.4%
TOTAL	4.7%	3.5%	78.7%	83.2%	16.6%	13.3%	100.0%	100.0%

Table 57. Non-home-based – Model vs MPD

SECTOR	SECTOR – CELLS SPLIT MODEL / MPD							
	1		2		3		TOTAL	
1 – Central	4.8%	2.0%	2.4%	6.6%	0.0%	0.2%	7.2%	8.8%
2 – Glasgow	11.5%	7.6%	64.9%	70.3%	0.3%	1.3%	77.6%	79.2%
3 – Rest	0.4%	0.2%	0.9%	1.3%	13.9%	10.5%	15.2%	12.0%
TOTAL	16.7%	9.8%	69.1%	78.1%	14.2%	12.0%	100.0%	100.0%

Table 58. All Traveller Types – Model vs MPD

SECTOR	SECTOR – CELLS SPLIT MODEL / MPD							
	1		2		3		TOTAL	
1 – Central	1.4%	0.5%	4.0%	4.2%	0.1%	0.2%	5.5%	4.9%
2 – Glasgow	6.0%	4.5%	72.0%	76.5%	0.7%	1.0%	78.6%	82.0%
3 – Rest	0.2%	0.2%	0.8%	1.0%	14.9%	11.9%	15.9%	13.0%
TOTAL	7.5%	5.2%	76.8%	81.7%	15.7%	13.0%	100.0%	100.0%

Figure 53. Home-based Regular Destination – Model vs MPD

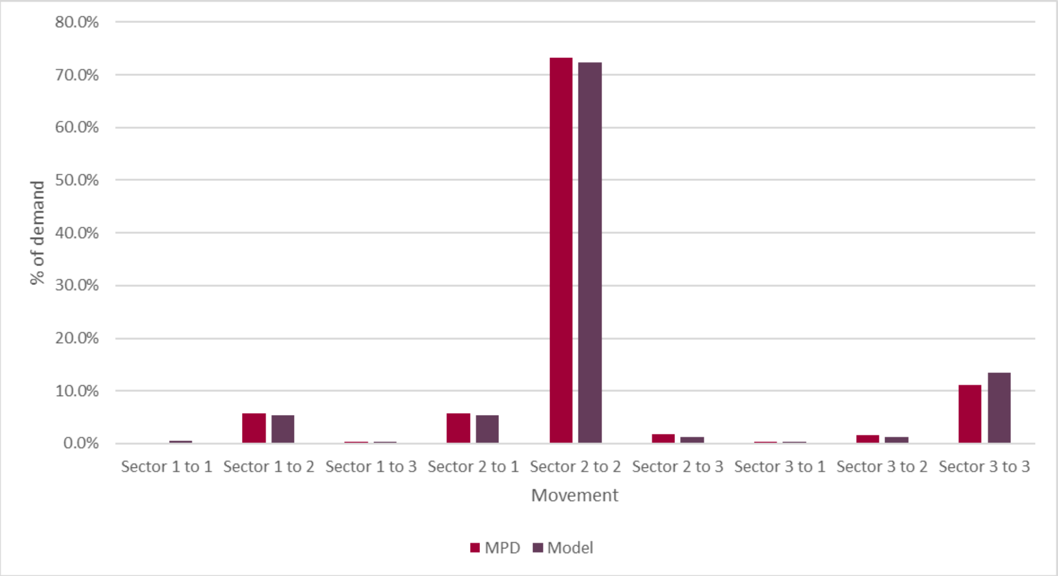


Figure 54. **Home-based Others – Model vs MPD**

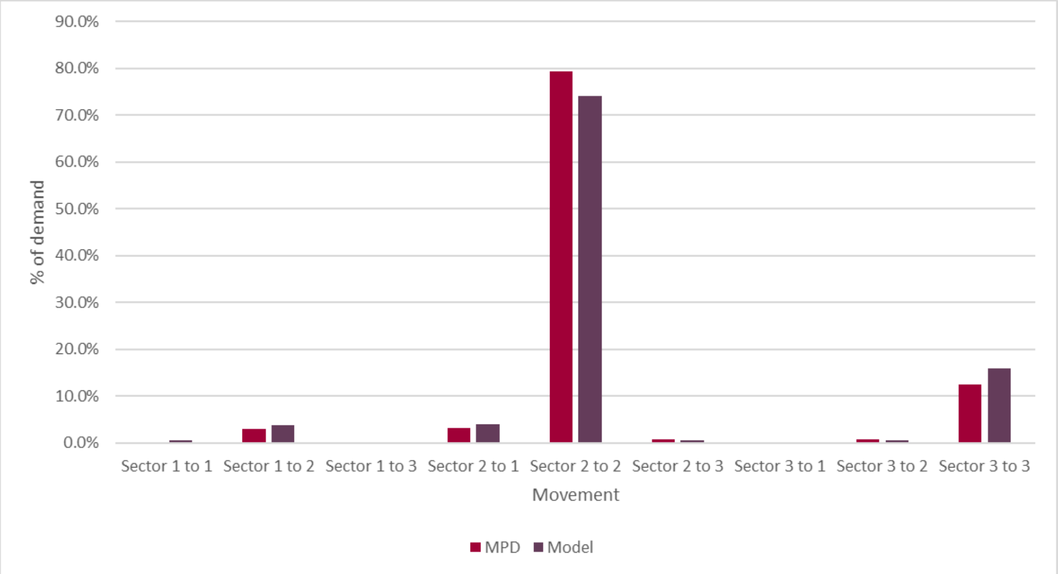


Figure 55. **Home-based Others – Model vs MPD**

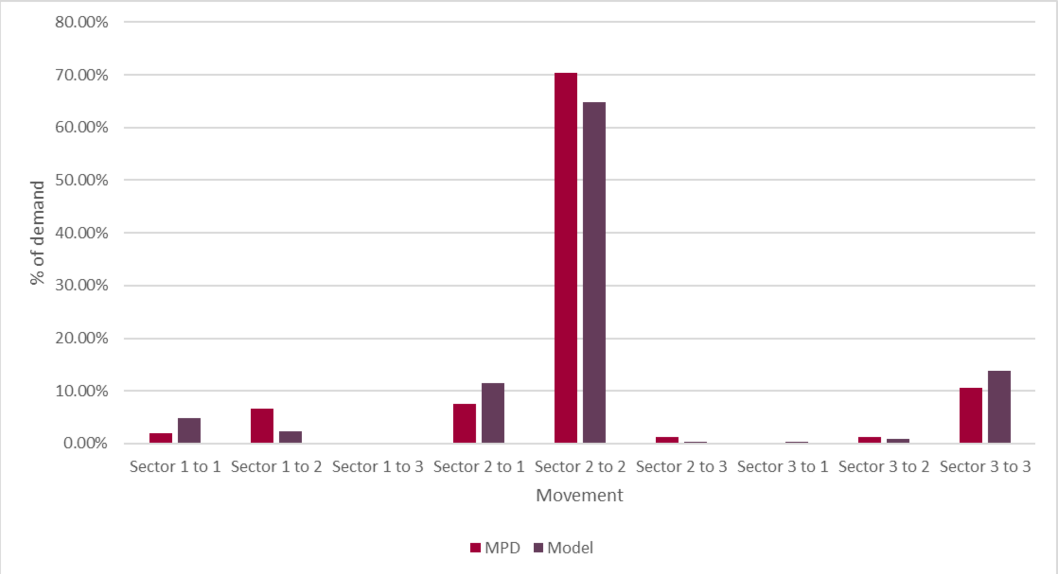
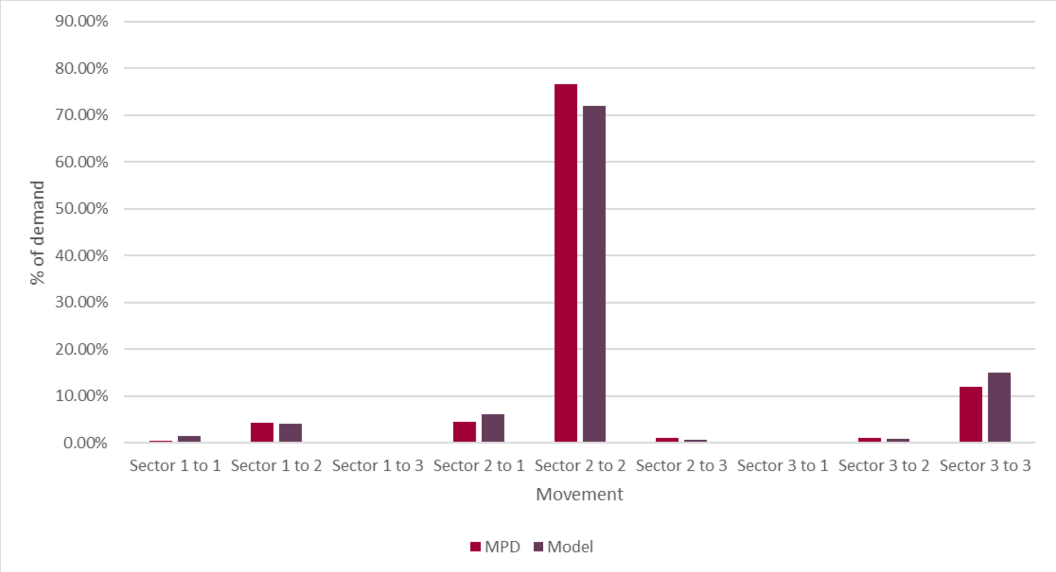


Figure 56. **All Traveller Types – Model vs MPD**



11.8.6 The four mobile phone data comparison tables reveal reassuringly-consistent patterns for the three journey purpose definitions, despite the differences in the methodologies for allocating journey purpose within these two data sets.

11.8.7 For the all traveller type analysis of Table 58, the model over-forecasts trips to the central area compared to mobile phone data, and similarly has more trips outside of Glasgow. Overall though there are no obvious outliers in the model predictions.

11.8.8 The equivalent analyses at the local authority sector level are provided in Appendix C.

11.9 Further Sector Analysis Checks

11.9.1 In addition, sector analysis checks were undertaken at a more disaggregate 33 sector system, and comparison between modelled and Census and modelled and mobile phone data.

11.9.2 The R^2 values for modelled vs MPD by trip type is shown in table 59 below:

Table 59. Modelled vs MPD by trip type

Trip Type	R^2	
	All	Intra-Sector removed
FH Regular	0.92	0.92
TH Regular	0.88	0.88
FH Non-Regular	0.91	0.91
TH Non-Regular	0.83	0.84
Non home based	0.86	0.85

11.9.3 The main comparisons (column All) is between the demand matrices (as output by the demand model prior to incremental adjustment) and the mobile phone data for the entire sectored matrix. As can be seen there is good agreement between the data sets, particularly for the "from home" datasets. This is to be expected as the tour proportions that govern the return trips in the demand model (derived from SHS data) are at a coarser 2 sector system (Glasgow city, rest of area), and consequently the sector analysis for the modelled data has a much higher level of symmetry between from home and to home than the mobile phone data.

11.9.4 The R^2 values for modelled vs Census by trip type is shown in table 60 below:

Table 60. Modelled vs CTTW by mode

Mode	R^2	
	All	Intra-Sector removed
Car	0.97	0.97
PT	0.86	0.87
Walk	0.97	0.96
Cycle	0.91	0.90

11.9.5 The R^2 values show a good level of fit between modelled mode and CTTW data.

11.10 Calculation of Incremental Adjustment Matrices

11.10.1 The final model input is the calculation of the incremental adjustment matrices, to ensure that the model reproduces the estimated matrices and thus the base year assignment model costs used in the final base year demand model run.

11.10.2 These were calculated through the reversal of the incremental adjustment process outlined in paragraph 8.5.3.

11.10.3 Appendix E provides a tabular analysis of the adjustment factors by user class and time period. The vast majority of additive factors are between -1 and 1 (greater than 99.5%), with the majority of multiplicative factors being between 0.5 and 0.9.

11.11 Realism Tests

11.11.1 We have analysed these results in terms of elasticity to fuel and fare in line with WebTAG guidance (Unit M2 – section 6.4).

11.11.2 In order to model the choices, the concept of utility is used where utility is defined on the lowest levels of the hierarchy as

$$e = \frac{(\ln(T^1) - \ln(T^0))}{(\ln(C^1) - \ln(C^0))}$$

Where:

T^1 is the demand output by the demand model using cost set1 ;
C^1 are the costs associated with cost set 1; and

e Is the output cost elasticity

11.11.3 For the fuel cost elasticity the demand measure is vehicle kilometres, for the fares elasticity the demand measure is public transport trips. The calculations have been performed for 'internal to internal' trips movements only, since all trips with an external trip end are not varied within the STRM model (as they are assumed to have been predicted by the national TMfS14 model).

11.11.4 The elasticity tests that have been performed

- 10% increase in fuel costs – coded through 88888 record in SATURN dat file;
- 10% increase in PT fares – coded through a factoring of the fares in the model; and
- 10% increase in car journey time – coded through an uplift in road skims.

11.11.5 The Car journey time elasticity test was performed over a single loop of the demand model. The convergence achieved for the fuel and pt fare tests are as follows:

- Fuel Cost - %GAP Loop 3 0.0252
- PT Fares - %GAP Loop 4 0.0108

11.11.6 The results of the elasticity tests for all time periods combined are reported in the table 61 below.

Table 61. Elasticity Check Analysis – All Periods Combined

DEMAND SEGMENT	FUEL COST ELASTICITY		FARES ELASTICITY		JOURNEY TIME	
	TARGET	MODEL	TARGET	MODEL	TARGET	MODEL
Employer's Business	-0.1 to -0.4	-0.03		-0.48		-0.11
Commuting		-0.24		-0.58		-0.19
Others		-0.31		-0.40		-0.17
Education		0.26		-1.16		-0.43
Retired		-0.32		-0.60		-0.18
All Journeys	-0.25 to -0.35	-0.25	-0.2 to -0.9	-0.56	<-2	-0.19

11.11.7 The results of the elasticity tests by time period are presented in tables 62 – 64.

Table 62. Elasticity Check Analysis – AM Period

DEMAND SEGMENT	FUEL COST ELASTICITY	FARES ELASTICITY	Journey time

	TARGET	MODEL	TARGET	MODEL	TARGET	MODEL
Employer's Business		-0.004		-0.138		-0.162
Commuting		-0.230		-0.569		-0.226
Others		-0.362		-0.213		-0.315
Education		0.259		-1.156		-0.427
Retired		-0.347		-0.463		-0.256
All Journeys	-0.25 to -0.35	-0.24	-0.2 to -0.9	-0.53	<-2	-0.28

Table 63. Elasticity Check Analysis – IP Period

DEMAND SEGMENT	FUEL COST ELASTICITY		FARES ELASTICITY		Journey time	
	TARGET	MODEL	TARGET	MODEL	TARGET	MODEL
Employer's Business		-0.062		-0.974		0.020
Commuting		-0.206		-0.539		0.018
Others		-0.264		-0.472		-0.125
Education		0.000		0.000		0.000
Retired		-0.308		-0.753		-0.753
All Journeys	-0.25 to -0.35	-0.25	-0.2 to -0.9	-0.56	<-2	-0.11

Table 64. Elasticity Check Analysis – PM Period

DEMAND SEGMENT	FUEL COST ELASTICITY		FARES ELASTICITY		Journey time	
	TARGET	MODEL	TARGET	MODEL	TARGET	MODEL
Employer's Business		-0.061		-0.731		-0.088
Commuting		-0.272		-0.598		-0.196
Others		-0.317		-0.262		-0.098
Education		0.000		0.000		0.000
Retired		-0.314		-0.238		-0.147
All Journeys	-0.25 to -0.35	-0.28	-0.2 to -0.9	-0.39	<-2	-0.13

11.11.8 The overall elasticity to fuel and public transport fares is within WebTAG guidance ranges.

11.11.9 Fuel elasticity for employers business is low at -0.03, though it should be noted that this rises with a 10% increase in fuel costs. This lower elasticity is partly explained by the effect reducing other trips, in particular commuters in the AM, have on the availability of parking.

11.11.10 The fuel elasticity for all trips is at the lower end of the guidance range, however it is effected by the elasticity for education trips. Investigations of the education elasticity results have revealed that the main reason is a cumulation of issues stemming from the initial source data for the generalised cost distribution not being segmented by mode.

11.11.11 This could be improved in later versions of the model, once more detailed information on school travel is available from the census.

11.11.12 The elasticity with respect to public transport fares is within guidance, again with the exception of education trips.

11.11.13 Furthermore, the fuel elasticities by trip length is in Table 65. It shows the expected pattern of an increasing elasticity as the trip length increases. It should be noted that for Education the last 6 observations can be discarded as the demand were less than 0.01, thus a small decrease will be mis-represented.

11.11.14 Overall, the realism tests provide evidence that the model is performing as expected for the majority of trips in the model.

The demand model has thus been calibrated to the observed generalised cost distributions and providing sufficiently robust elasticities for use in scheme assessment.

Table 65. Elasticity Check Analysis – All Period by Trip Length

TRIP LENGTH (KM)	EMPLOYER'S BUSINESS	COMMUTING	OTHERS	EDUCATION	RETIRED	ALL JOURNEYS
Less Than 5	0.03	0.28	0.18	0.46	0.27	0.23
5 - 10	0.04	0.25	0.08	0.2	0.11	0.13
10 - 15	0.08	0.17	-0.09	-0.03	-0.04	0.01
15 - 20	0.04	-0.04	-0.38	-0.1	-0.35	-0.21
20 - 25	0	-0.15	-0.6	-0.53	-0.58	-0.34
25 - 30	0.01	-0.33	-0.79	-0.85	-0.83	-0.47
30 - 35	-0.03	-0.49	-1.09	-1.38	-1.13	-0.62
35 - 40	-0.07	-0.61	-1.16	-1.66	-1.44	-0.68
40 - 45	-0.08	-0.79	-1.14	-1.68	-1.6	-0.76
45 - 50	-0.22	-0.91	-0.9	-2.17	-1.77	-0.8
50 - 55	-0.13	-1.06	-1.09	-2.63	-2	-0.9
55 - 60	-0.26	-1.13	-1.22	-2.51	-2.11	-0.97
60 - 65	-0.37	-1.4	-0.83	-3.07	-2.26	-1.11
65 - 70	-0.51	-1.55	-0.97	-3.02	-2.52	-1.25
70 - 75	-0.35	-1.59	-0.45	-3.74	-2.4	-1.17
75 - 80	-0.69	-1.78	-0.24	-7.27	-1.12	-1.31
80 - 85	-0.98	-2.12	0.63	0	-1.69	-1.62
85 - 90	-0.65	-1.87	-0.37	0	-3.28	-1.44
90 - 95	-0.77	-1.96	-0.32	0	-2.76	-1.49
95 - 100	-1.11	-2.25	-0.52	0	-3.32	-1.78
Greater than 100	-1.13	-2.66	-0.95	0	-3.54	-2.08

12. CONCLUSIONS / SUMMARY

12.1.1 This model development report has documented the development of the SRTM demand modelling component, covering the key sub-models of:

- Initial Simple Tour Mode and Destination Choice;
- One Way Trip Mode and Destination Choice;
- Free Workplace Parking Model;
- Parking Distribution Model; and
- Park and Ride Model.

12.1.2 The methods, input parameters and base year input data for these models have been documented in the preceding chapters.

12.1.3 The demand model have been calibrated to a combination of census and Scottish Household Survey data (see Chapter 2 for data analysis).

12.1.4 The performance of the model against observed mode shares and generalised cost distributions is good as evidenced in Chapter 11.

12.1.5 The outcomes of the free workplace parking and parking distribution models appear plausible.

12.1.6 The overall level of response to changes in costs within the demand model is within WebTAG guidance, providing confidence in the use of the model for testing of interventions (see Chapter 11).

12.1.7 Overall, the demand model components have been successfully developed, tested and integrated to produce an SRTM demand model that operates within guidance elasticity.

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