Oxfordshire Strategic Model

Public Transport Model Report

Oxfordshire County Council

March 2015

Plan Design Enable

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This document has 822 pages including the cover.

Document history

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Rev 2.0	Final Report	OS	WW	AA	AA	12/03/15

Table of contents

Tables

Figures

1. Introduction

Oxfordshire County Council has commissioned Atkins to develop a suite of multi-modal strategic models to provide evidence to support robust future assessments for funding bids and scheme prioritisation, particularly in regard to transport scheme assessments that meet the DfT Web Transport Appraisal Guidance (WebTAG). The strategic model will also help develop business cases for future major schemes, route strategies and carry out scenario testing of the transport impacts of new development and mitigation measures.

The Oxfordshire Strategic Model (OSM) is a new, fit-for-purpose transport model that has been developed specifically to assess transport interventions in Oxfordshire. Post-SEP submission, it will be used by the LTB and LEP to provide guidance on detailed scheme design and to produce the value-for-money elements at the three scheme business case stages. Within these three stages, there will be particular emphasis on using model to identify the impact of transport and development in Oxfordshire. The model is fully multi-modal and WebTAG compliant.

1.1. Key Model Design Considerations

The key consideration in developing the WebTAG compliant OSM was to provide an evidence base for the appraisal of major highway and public transport schemes. The major interventions are principally around Bicester, Oxford, and the Science Vale corridor. The model needs to pay special attention to the A40 corridor between Witney and J8 of the M40, as well as public transport and P&R.

The principal objective of the OSM is to appropriately represent travel conditions on the highway and public transport networks for the appraisal of various schemes. The OSM should provide:

- changes in traffic flows for input to the environmental appraisal of schemes; and
- changes in travel costs and changes in demand for different modes of transport for input to the economic appraisal.

The potential interventions for appraisal will include major highway improvements, large traffic management schemes, and large-scale, complex public transport schemes. The OSM needs to have the following capabilities:

- be able to reflect the impact of changes in land use policies, economic conditions and interventions on travel demand;
- be suitable for scenario development tests, using less detailed modelling; and
- be capable of more detailed modelling of schemes to be put forward for inclusion in funding programmes.

Another requirement stipulated by OCC for the model is that the run time should not exceed an overnight 16 hour period.

The OSM modelling system consists of three key elements:

- a Road Traffic Model (RTM) representing vehicle-based movements across Oxfordshire for a typical 2013 morning peak hour (08:00 – 09:00), an average inter-peak hour (10:00 – 16:00) and an evening peak hour (17:00 – 18:00);
- a Public Transport Model (PTM) representing bus and rail-based movements across the same area and time periods; and
- a Main Demand Model (MDM): a five-stage multi-modal incremental demand model that estimates frequency choice, main mode choice, time period choice, destination choice, and sub mode choice in response to changes in generalised costs across the 24-hour period (07:00 – 07:00).

This report deals with the PTM element of the model.

1.2. Scope of Report

This Model Development Report consists of nine sections. Following this introductory section:

- Section Two presents the validation criteria and acceptability guidelines for the PTM;
- Section Three gives an overview of the key features of the model;
- Sections Four and Five give details of the network and matrix development;
- Section Six presents some key assignment results;
- Section Seven presents the calibration and validation data used in the development of the PTM, as well as the calibration and validation results; and
- a summary of the model development is presented in Section Eight.

2. Model Standards

2.1. Validation Criteria and Acceptability Guidelines

As indicated in the public transport model guidelines in TAG Unit M3-2 *Public Transport Assignment Modelling*, the PTM validation should include:

- validation of the trip matrix;
- network and service validation; and
- assignment validation

2.2. Trip Matrix Validation

2.2.1. Bus Matrix Validation

TAG Unit M3-2, paragraph 7.1.2 states that "*Validation of the **trip matrix** should involve comparisons of assigned and counted passengers across complete screenlines and cordons (as opposed to individual services). **At this level of aggregation, the Department's suggested guideline is that the differences between assigned and counted flows should, in 95% of the cases, be less than 15%.***"

It was not possible to complete a full trip matrix validation for the PTM because independent screenline and cordon counts were not available. However, a **calibration** was carried out, which relied on the same data sources as were used to build the matrices.

The trip matrix calibration focused on three cordons around Oxford, Bicester and Didcot. Further details on the data sources, as well as the calibration results, are presented in Chapter 7.

2.2.2. Rail Matrix Validation

No cordon or screenline counts were available for rail matrix validation.

2.3. Network and Service Validation

The PTM bus network is identical in structure to the **validated highway network. Checks on the accuracy of the coded network geometry are covered in the RTM Development** Report. The PTM network validation includes:

- checks on the geometry of the rail network, including station to station distances;
- checks on modelled rail journey times, which are coded to match the timetable; and
- a comparison of modelled bus journey times (which are linked to times on the highway network) with timetabled times for a selection of routes covering the main bus corridors.

The service validation includes checking the coding of bus and rail services against the timetables in terms of service frequencies and stopping patterns.

2.4. Assignment Validation

TAG Unit M3-2, paragraph 7.1.6 states that "***Across modelled screenlines, modelled flows should, in total, be within 15% of the observed values. On individual links in the network, modelled flows should be within 25% of the counts**, except where observed hourly flows are particularly low (less than 150 passengers per hour).*"

A large number of the observed link counts that were collected have flows less than 150. In order to give some measure of the fit of the model to counts less than 150, we have calculated the GEH statistic, a definition of which is given below. A GEH of less than 5 indicates a good fit of the modelled link flow to the observed count.

Whilst WebTAG does not specify an overall objective for the calibration/validation, we have aimed to achieve 85% of links meeting the criteria of:

- Observed count > 150: Modelled boardings/alightings within 25% of observed
- Observed count < 150: GEH < 5

GEH Statistic

As well as differences in flow, the GEH statistic has been included in the tables below as an indicator of ‘goodness of fit’, i.e. the extent to which the modelled flows match the corresponding observed flows.

$$GEH = \sqrt{\frac{(M-C)^2}{0.5 \times (M + C)}}$$

where M = modelled flow and C = observed flow

The data available for model calibration and validation is described in Chapter 7.

3. Key Features of the PTM

3.1. Base Year

The OSM has a 2013 base year and represents the travel conditions for a typical April weekday.

3.2. Modelled Area

The OSM PTM is identical in scope and network structure to the OSM RTM. In the OSM the Area of Detailed Modelling (ADM) covers the area bounded by:

- Bicester to the north;
- Wallingford to the east;
- Burford and Witney to the west; and
- Wantage and Didcot to the south.

The Fully Modelled Area (FMA) covers the rest of Oxfordshire plus some hinterland areas. Figure 4-1 shows the extent of ADM and FMA for OSM.

The External Area covers the rest of Great Britain in a skeletal form.

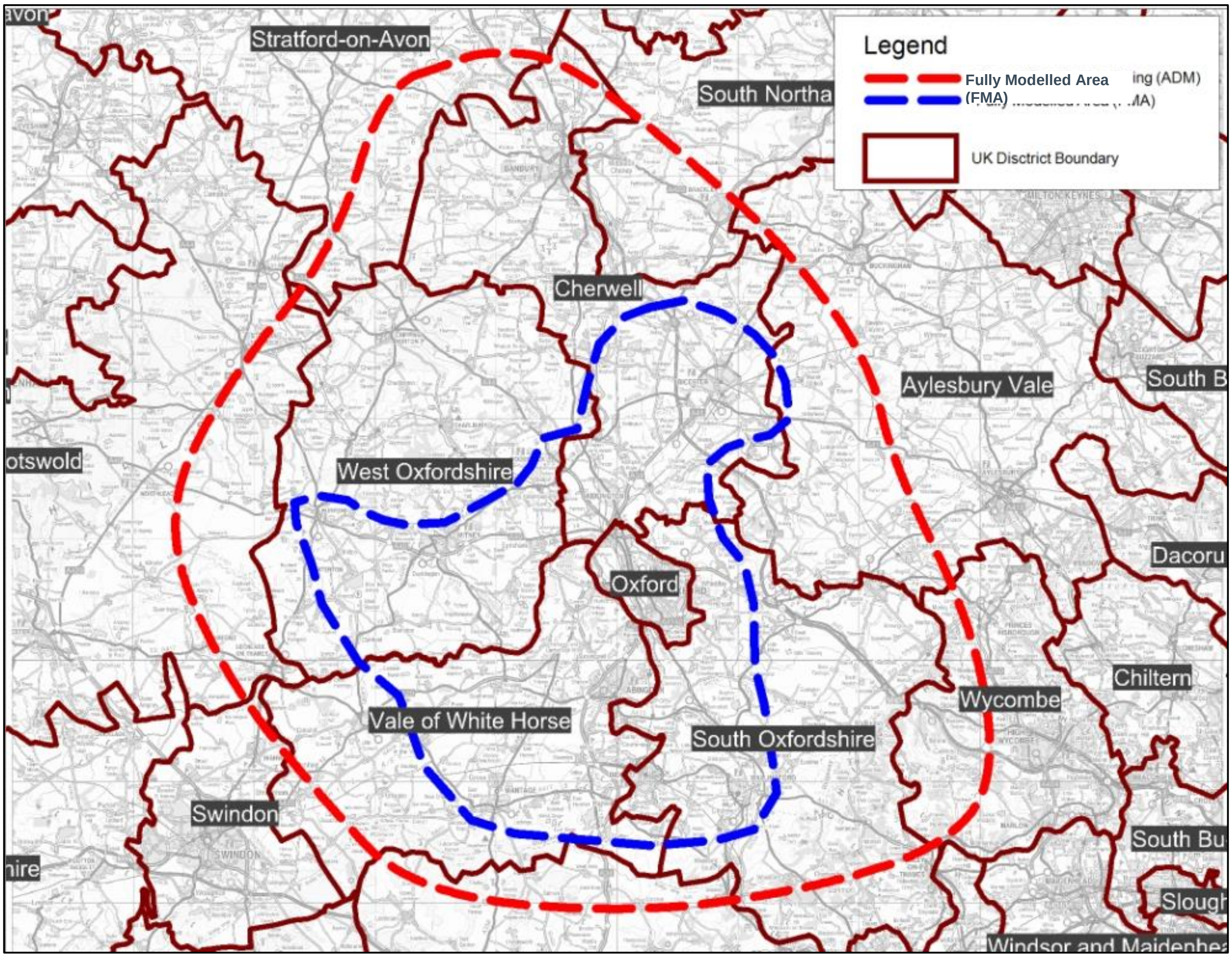


Figure 3-1 Area of Detailed Modelling and Fully Modelled Area for OSM

3.3. Zoning System

The PTM has an identical zoning system to the RTM. A summary of the zoning structure is given below.

Table 3-1 OSM Zoning System

Area	No. of Zones
Oxford	130
Didcot / Wallingford / Wantage	42
Bicester	26
Abingdon	30
Witney	25
Banbury	7
Rest of Oxfordshire	293
Hinterland	115
Rest of UK	36
Total	704

Figure 3-2 OSM Zones in Oxfordshire

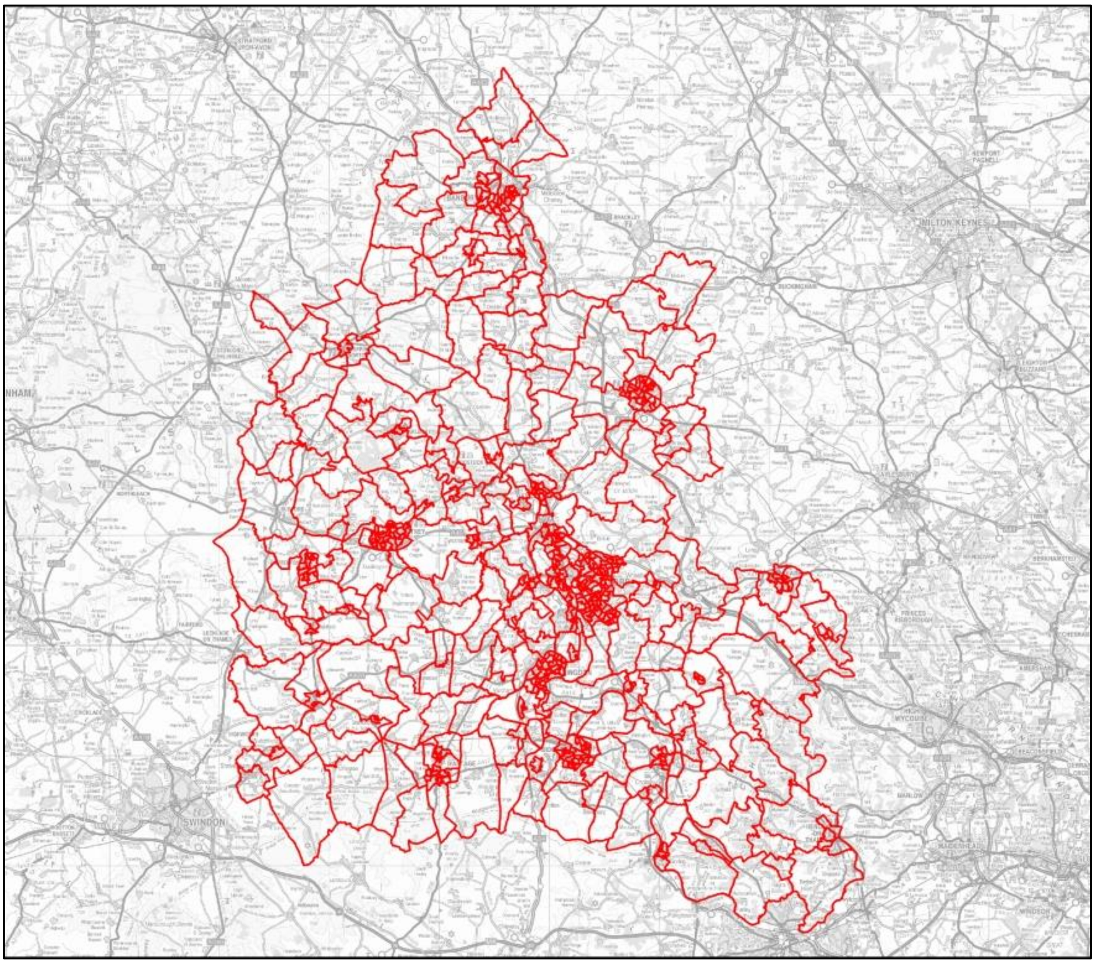
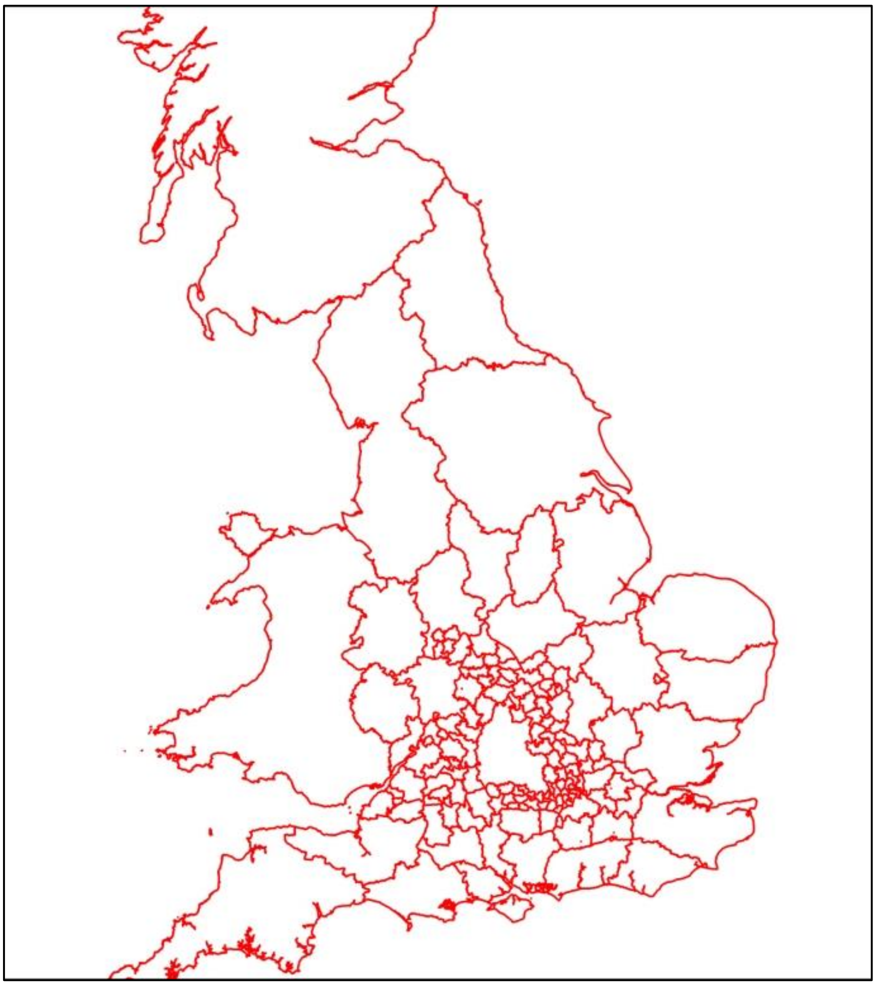


Figure 3-3 OSM Zones in the Hinterland and External Area



3.4. Network Structure

The PTM has been developed to represent two public transport modes:

a. bus; and
b. rail.

In addition, the model also includes a bus-based Park & Ride (P&R) mode. The performance of the park and ride sub-model is separately reported within the MDM development report.

Separate provision has been reserved for new modes such as LRT and BRT[1], and the assignment procedures allow the flexibility of integrating the new modes into the MDM.

For the bus mode, the OSM PTM inherits the network structure from the OSM RTM. The rail network has been coded separately to represent all rail lines in the Fully Modelled Area and its hinterland.

3.5. User Classes

The public transport assignment uses a single user class.

[1] Light rail transit and bus rapid transit

3.6. Assignment Methodology

The Public Transport Assignment Model uses the standard transit assignment implemented in EMME, i.e. a multipath assignment, based on the computation of optimal strategies. Further details of the assignment methodology may be found in the EMME reference manual.

3.7. Generalized Cost Formulations and Parameter Values

The generalised cost function used for the public transport assignment routing, measured in units of time (minutes), is given by:

$$G_{PT} = V_{wk}{*}A + V_{wt}{*}W + T + B$$

where:

V_{wk} is the weight applied to time spent walking (walk time weight);

A is the total walking time to and from the services;

V_{wt} is the weight applied to time spent waiting;

W is the total waiting time for all services used on the journey;

T is the total in-vehicle time; and

B is the total boarding penalty applied for each service boarded on the journey

The public transport assignment model uses parameters based on those provided in WebTAG Unit M3-2, which in turn are derived from work undertaken by Institute of Highways and Transportation to establish guidelines for urban transport strategies and further work commissioned by the DfT on the value of travel time savings. Further details, including the various references, may be found in the WebTAG Unit.

The parameter values for assignment are set out below in Table 6.1. In the EMME assignment, the modelled wait time is controlled by the 'wait time factor' of 0.5, indicating that the wait time is set at half the service headway.

Table 3-2 Assignment Parameters

Parameter	Value
Wait time factor	0.5
Wait time weight	2.5
Walk time weight	2.0
Boarding penalty	0 to 20*

** Adjusted as part of the calibration process.*

3.8. Fares

The public transport sub-mode choice (i.e. Bus vs Rail) is undertaken within the MDM based on the standard WebTAG generalised cost formulation (which includes fares). The PTM (assignment) does not consider the impact of fares. The PTM determines the route choice (within each mode) and whilst there will be some influence of fares, it is unlikely to be significant, because:

- Bus Services in Oxfordshire are provided principally by Stagecoach, Oxford Bus Company and Thames Travel. Typically a competitive stage based fare system with a range of day and season ticket types is provided by each bus operator, which limits passenger's choice to choose alternative routes in order to reduce fare costs. Meanwhile rail fares are distance-based and the P&R mode has a flat fare system;
- The choice of route is sensitive to the difference in the total cost of the journey rather than the absolute cost, and the influence of fare is small compared to the weights attached to In-Vehicle Time, Wait Time and Interchange penalties;
- There are several ticket types such as day returns and season tickets which are purchased independently of route choice; and
- The fare differentials between realistic competing routes for the same O-D pair will be small.

3.9. Bus Journey Times

The bus network is created from the OSM RTM. This enables a linkage to be established between highway travel times and bus travel times such that, in forecasting mode, the impact of increasing congestion levels on bus travel times is represented.

This linkage also allows the impact on bus journey times of new bus lanes and bus priority measures at junctions to be modelled. At the same time, it models the effects of capacity reduction on general traffic, and the effect this has, in turn, on bus journey times. Further details of the mechanism used are given in Appendix A.

4. Network Development

4.1. Bus network

As noted above, the PTM bus network is derived directly from the RTM. Checks on the accuracy of the coded network geometry are covered in the RTM Development Report.

4.2. Bus Routes

The PTM includes the majority of bus routes serving the major population centres in the Fully Modelled Area. Certain low-frequency and cross-country services have been omitted outside of the Area of Detailed Modelling. Bus Services in Oxfordshire are provided principally by Stagecoach, Oxford Bus Company and Thames Travel.

The bus network is illustrated below in Figure 4-1. The links shown in red have bus services running along them. Figure 4-2 shows the number of buses per hour in Oxford city centre in the AM Peak. Table 4-1 summarises the bus services included in the base year PTM.

Figure 4-1 OSM Bus Network (AM Peak)

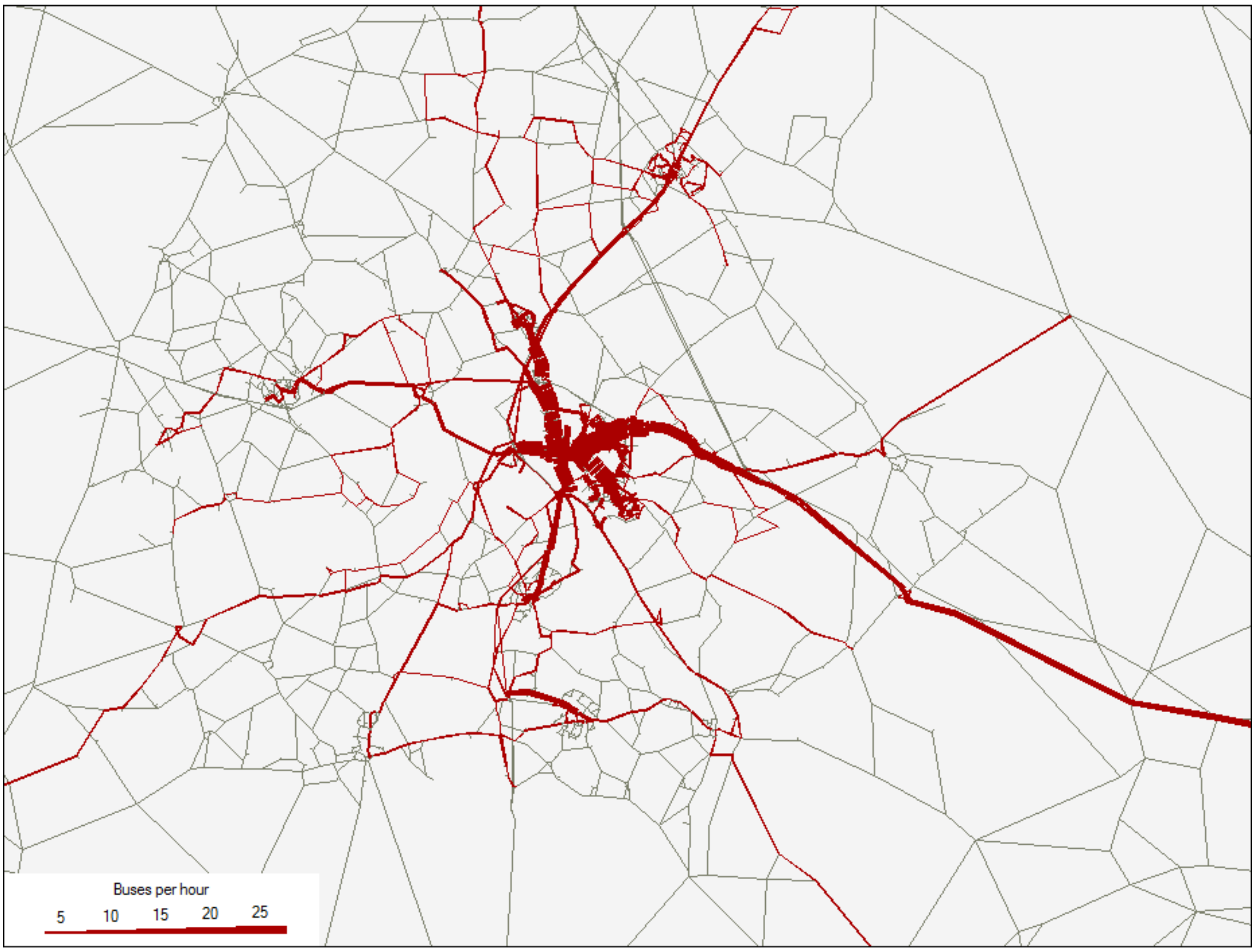


Figure 4-2 Buses per Hour in Oxford City Centre in the AM Peak

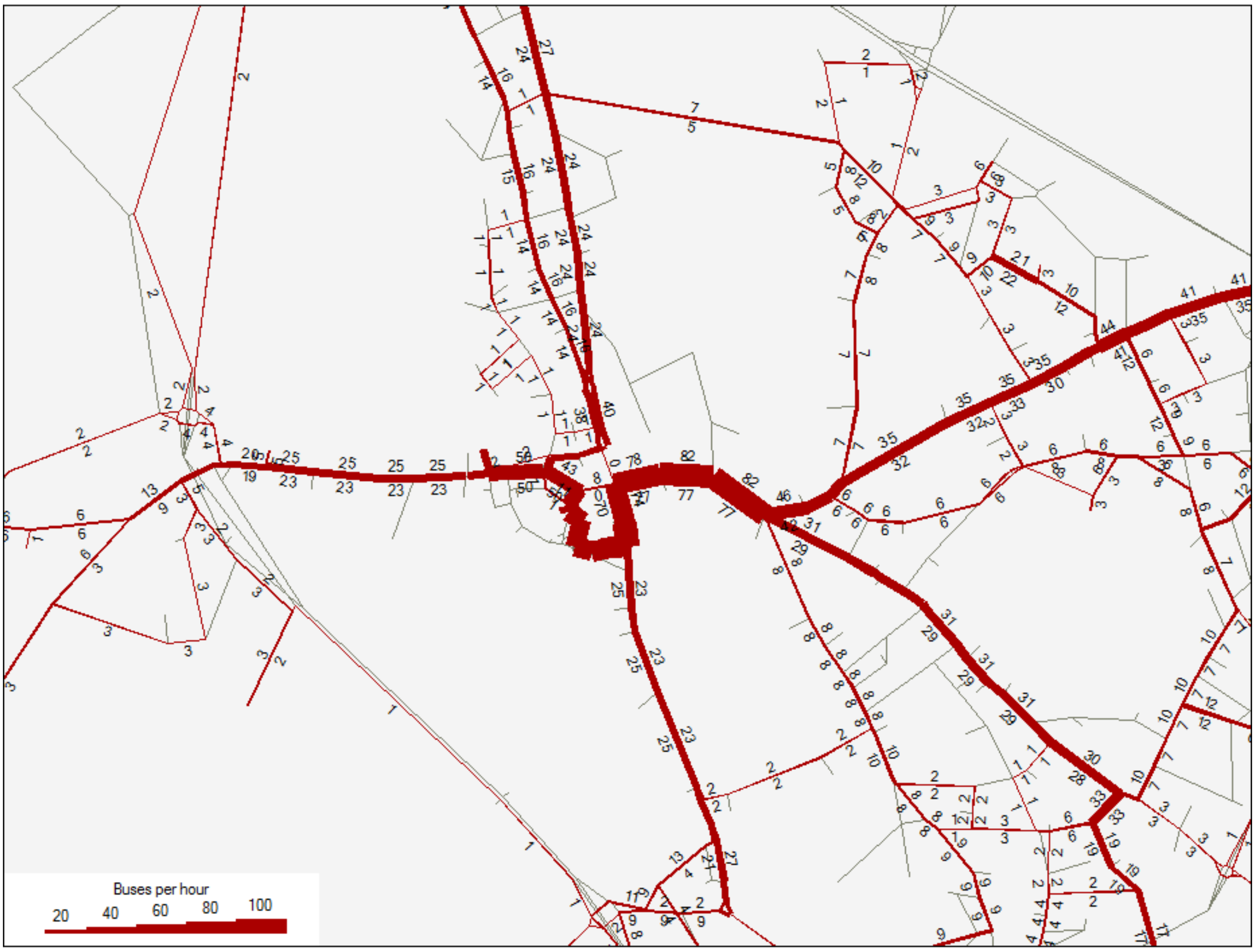


Table 4-1 OSM Bus Services

Service	Route	Operator	Buses per hour (in each direction)		
			AM Peak	Inter Peak	PM Peak
1	Blackbird Leys - Oxford	Stagecoach	7.5	7.5	7.5
2/2A/2B/2C/2D	Kidlington - Oxford	Oxford Bus and Stagecoach	8.0	8.0	8.0
3	Rose Hill - Oxford	Oxford Bus	7.5	8.0	7.1
4	Abingdon - Wood Farm	Oxford Bus	1.0	1.0	1.0
4A	Elms Rise - Wood Farm	Oxford Bus	3.0	3.0	3.0
4B	Cumnor - Wood Farm	Oxford Bus	0.8	1.0	0.7
4C	Dean Court - Wood Farm	Oxford Bus	0.9	1.0	1.0
5	Blackbird Leys - Oxford	Oxford Bus	7.5	7.5	7.5
6	Lower Wolvercote - Oxford	Oxford Bus	4.0	4.0	4.0
8	Oxford - Barton	Oxford Bus	6.3	7.0	6.3
9	Risinghurst - Oxford	Oxford Bus	2.0	2.0	2.0
10	John Radcliffe - Oxford	Stagecoach	6.0	6.0	5.0
11	Witney - Oxford	Stagecoach	1.0	1.0	1.0
12	Greater Leys - Oxford	Stagecoach	2.0	2.0	2.0

Service	Route	Operator	Buses per hour (in each direction)		
			AM Peak	Inter Peak	PM Peak
13	Oxford - JohnRadcliffe	Oxford Bus	3.2	3.0	3.0
14/14A	John Radcliffe - Oxford	Stagecoach	2.4	2.0	1.8
16/16A	Minchery - Oxford	Stagecoach	2.0	2.0	2.0
17	Cutteslowe - Oxford	Stagecoach	0.8	0.9	0.8
18	Bampton - Oxford	Stagecoach	0.5	1.0	1.0
20	UnipartHouse - RoseHill	Stagecoach	1.0	1.0	1.0
21	Bicester - Chesterton -	Thames Travel	2.0	2.0	2.0
22	Bicester - Caversfield	Thames Travel	1.3	1.2	1.0
23	Bicester - Caversfield	Thames Travel	0.7	1.0	1.0
23 (Oxf)	Redbridge - John Radcliffe	Oxford Bus	0.0	2.0	0.0
24	Bicester - Churchill Road	Thames Travel	1.3	2.0	2.0
25	Bicester - Kidlington	Thames Travel	0.5	0.5	0.0
25A	Bicester - Oxford	Thames Travel	0.9	1.0	2.0
26	Bicester - Kingsmere	Stagecoach	1.8	2.0	1.5
31	Wantage - Oxford	Stagecoach	1.0	1.0	1.0
32	Wantage - Abingdon	Thames Travel	1.0	0.8	0.0
35	Abingdon - Oxford	Oxford Bus	4.0	4.0	4.0
36	Wallingford - Wantage	Thames Travel	1.0	1.0	1.0
44	Abingdon - Oxford	Heyfordian	0.7	0.3	0.7
63	Southmoor - Oxford	BrookBus	0.3	0.5	0.7
66	Swindon - Oxford	Stagecoach	2.0	1.9	2.0
97	Didcot - Berinsfield	Thames Travel	0.0	0.7	0.0
98	Didcot - Orchard Centre	Thames Travel	2.0	2.0	3.3
103	Little Milton - Oxford	Heyfordian	1.0	0.5	0.5
104	Denton - Oxford	Heyfordian	0.0	0.5	0.5
108	Forest Hill - Oxford	Heyfordian	0.5	0.3	0.5
280	Oxford - Aylesbury	Arriva	2.8	3.0	2.7
300	Peartree - Redbridge (P&R)	Oxford Bus	5.6	6.7	5.9
400	Thornhill - Seacourt (P&R)	Oxford Bus	5.0	4.9	4.9
500	Water Eaton - Oxford (P&R)	Oxford Bus	3.8	4.1	4.0
700	Kidlington - Headington (P&R)	Stagecoach	2.8	3.0	2.5
737	Oxford - Stansted Airport	Brooks Bus	0.4	0.4	0.4
800	Thornhill - John Radcliffe (P&R)	Stagecoach	3.0	3.0	2.7
900	Thornhill - Headington (P&R)	Stagecoach	3.0	3.0	2.7
LGW	Gatwick Airport - Oxford	Oxford Bus	1.0	1.0	1.0
LHR	Heathrow Airport - Oxford	Oxford Bus	2.0	2.0	2.0
M10	Milton Park - Didcot Parkway	Brooks Bus	4.6	2.2	4.6
S1	Carterton - Oxford	Stagecoach	4.3	4.1	4.3
S2	Brize Norton - Oxford	Stagecoach	1.8	2.0	2.0
S3	Chipping Norton - Oxford	Stagecoach	3.0	2.0	3.3
S4	Banbury - Oxford	Stagecoach	1.0	1.0	1.0
S5	Bicester - Oxford	Stagecoach	4.2	4.0	3.9

Service	Route	Operator	Buses per hour (in each direction)		
			AM Peak	Inter Peak	PM Peak
T1	Watlington – Oxford	Thames Travel	1.0	1.0	1.0
T2	Abingdon – Oxford	Thames Travel	1.0	1.0	1.0
T3	Oxford Science Park - Oxford	Thames Travel	1.3	1.3	2.0
TUBE	London Victoria - Oxford	Stagecoach	3.1	4.0	3.6
U1	Harcourt Hill - Wheatley	Oxford Bus	2.5	2.0	2.0
U1B	Oxford – Wheatley	Oxford Bus	1.3	2.0	2.0
U5	New Marston - Oxford	Oxford Bus	1.3	2.0	2.0
U5X	Wheatley – Oxford	Oxford Bus	1.3	1.4	1.2
Bic Shuttle	Bicester Village Shuttle	Grayline	6.0	6.0	6.0
X2	Wallingford - Oxford	Oxford Bus	1.3	1.3	1.3
X3	Abingdon – Oxford	Oxford Bus	4.1	3.0	4.2
X5	Oxford – Cambridge	Stagecoach	2.2	2.0	2.0
X13	Abingdon - John Radcliffe	Oxford Bus	2.5	3.0	3.2
X30	Wantage – Oxford	Stagecoach	1.2	2.1	1.3
X32	Chilton – Oxford	Thames Travel	1.0	1.0	1.0
X39	Reading – Oxford	Thames Travel	1.0	1.0	1.0
X40	Reading – Oxford	Thames Travel	1.1	1.0	1.0
X90	London Victoria - Oxford	Oxford Bus	3.0	3.3	3.4

4.3. Rail Network

The rail network includes all stations in Oxfordshire and the surrounding area, together with a series of indicative stations outside this area.

Services were coded according to Autumn 2013 timetables, with journey times 'hard-coded' into the line descriptions. All rail services calling at stations in Oxfordshire in the modelled time periods (i.e. 08:00-09:00, average hour between 10:00-16:00 and 17:00-18:00) were included. The main focus of the rail network was upon rail services that provide local movements within Oxfordshire and from nearby external zones to/from Oxfordshire. Other services (for example, mainline services on the First Great Western line) appear in the rail network model in only a generalised manner.

Figure 4-3 shows the rail network graphically. A list of stations included in the network is given in Table 4-2.

Figure 4-3 OSM Rail Network Showing Trains Per Hour in the AM Peak

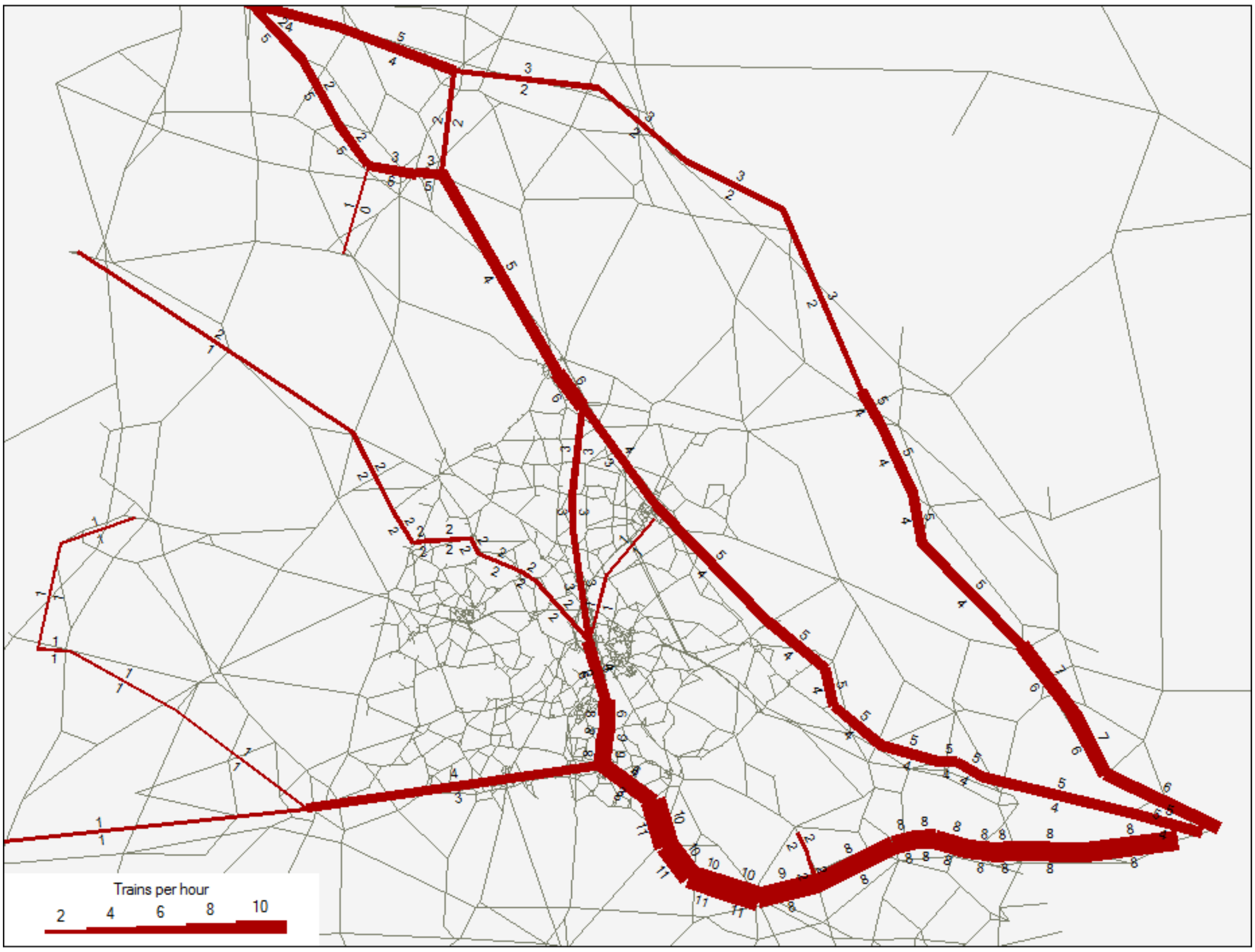


Table 4-2 Rail Stations in the OSM

Node number	Code	Station	Node number	Code	Station
100	PAD	London Paddington	141	WOS	Worcester Shrub Hill
101	STL	Southall	142	ISP	Islip
102	IVR	Iver	143	BIT	Bicester Town
103	LNY	Langley Bucks	144	MYB	London Marylebone
104	SLO	Slough	145	WCX	Wembley Stadium
105	BNM	Burnham Bucks	146	GER	Gerrards Cross
106	TAP	Taplow	147	SRG	Seer Green
107	MAI	Maidenhead	148	BCF	Beaconsfield
108	TWY	Twyford	149	HWY	High Wycombe
109	RDG	Reading	150	SDR	Saunderton
110	TLH	Tilehurst	151	PRR	Princes Risborough
111	PAN	Pangbourne	152	HDM	Haddenham & Thame Parkway
112	GOR	Goring & Streatley	153	BCS	Bicester North
113	CHO	Cholsey	154	LMS	Leamington Spa
114/115	DID	Didcot Parkway	155	WRW	Warwick
116	SWI	Swindon Wilts	156	WRP	Warwick Parkway
117	BPW	Bristol Parkway	157	HTN	Hatton

Node number	Code	Station	Node number	Code	Station
118	KEM	Kemble	158	LPW	Lapworth
119	STD	Stroud	159	SOL	Solihull
120	SHU	Stonehouse	160	BMO	Birmingham Moor Street
121	GCR	Gloucester	161	SAV	Stratford Upon Avon
122	CNM	Cheltenham Spa	162	COV	Coventry
123	APF	Appleford	163	BHI	Birmingham International
124	CUM	Culham	164	BHM	Birmingham New Street
125	RAD	Radley	165	WGV	Wargrave
126/127/128	OXF	Oxford	166	SHI	Shiplake
129	TAC	Tackley	167	HOT	Henley-on-Thames
130	HYD	Heyford	168	RUG	Rugby
131	KGS	Kings Sutton	169	LBK	Long Buckby
132	BAN	Banbury	170	NMP	Northampton
133	HND	Hanborough	171	MKC	Milton Keynes Central
134	CME	Combe Oxon	172	BLY	Bletchley
135	FIN	Finstock	173	LBZ	Leighton Buzzard
136	CBY	Charlbury	174	CED	Cheddington
137	AUW	Ascott-under-Wychwood	175	HML	Hemel Hempstead
138	SIP	Shipton	176	WFJ	Watford Junction
139	KGM	Kingham	177	HRW	Harrow & Wealdstone
140	MIM	Moreton-in-Marsh	178	EUS	London Euston

4.4. Centroid Connectors

Centroid connectors for the PTM were initially taken from the RTM, but these were subsequently adjusted to improve routing in the PTM. Centroid connector lengths reflect the actual distance of zone centroids from the public transport network.

The rail network also includes a number of connectors that represent station access/egress by car. These are coded with a speed of 70kph, as opposed to 5kph for walk access/egress.

4.5. Boarding Penalties

A number of boarding penalties at specific nodes were applied to dissuade unrealistic interchanges. The values were calibrated specifically for the model, to ensure a realistic assignment of trips, and include:

a. Line based penalties for specific services (ut2);
b. Node based penalties for selected bus nodes (ui1); and
c. Node based penalties at selected rail stations (ui1).

5. Trip Matrix Development

5.1. Overview of Methodology

The trip matrix development methodology aims to make the best use of each of the available sources of origin-destination data, namely:

- onboard origin-destination survey data and Electronic Ticket Machine (ETM) data for bus; and
- origin-destination survey data and MOIRA ticketing data for rail.

Separate bus, P&R and rail matrices were produced for each time period at the OD-level. The process is described in detail in the sections below.

Initially, the matrices were built at the all purpose level, as required for the PTM, which has a single user class for assignment. Subsequently, the matrices were disaggregated by trip purpose using proportions derived from the survey data on a sector-sector basis. Details of the purpose splits and demand totals by trip purpose are given in the Demand Model report.

5.2. Bus Travel Demand Data

Two sources of bus origin-destination data were used to build the bus demand matrices:

- Onboard bus origin-destination surveys undertaken specifically for the development of the OSM in November 2013; and
- ETM data obtained from the main bus operators in Oxfordshire:
  - Oxford Bus Company and Thames Travel supplied data for the period 15 April 2013 to 10 May 2013, providing 19 days of aggregated weekday data in total.
  - Stagecoach Oxford supplied data for the period 1 to 25 October 2013, providing 19 days of aggregated weekday data in total.

ETM data were obtained for most of the bus routes in the model, while the surveys only covered a selection of routes. Some longer services were only surveyed over part of their route. For a small number of routes, neither source was available. Table 5-1 presents a summary of the data available for each route.

Table 5-1 Summary of Bus Demand Data by Route

Service	Route	Survey	ETM
1	Blackbird Leys - Oxford	Full Route	Yes
2	Kidlington - Oxford	Partial: Water Eaton - Oxford	Yes
2A/2B/2C/2D	Kidlington - Oxford	No	Yes
3	Rose Hill - Oxford	Full Route	Yes
4	Abingdon - Wood Farm	Full Route	Yes
4A	Elms Rise - Wood Farm	Partial: Botley - Wood Farm	Yes
4B	Cumnor - Wood Farm	Partial: Botley - Wood Farm	Yes
4C	Dean Court - Wood Farm	Partial: Botley - Wood Farm	Yes
5	Blackbird Leys - Oxford	Full Route	Yes
6	Lower Wolvercote - Oxford	No	Yes
8	Oxford - Barton	No	Yes
9	Risinghurst - Oxford	No	Yes
10	John Radcliffe - Oxford	Partial: Headington - Oxford	Yes
11	Witney - Oxford	No	Yes
12	Greater Leys - Oxford	Full Route	Yes
13	Oxford - JohnRadcliffe	Full Route	Yes

Service	Route	Survey	ETM
14/14A	John Radcliffe - Oxford	Full Route	Yes
16/16A	Minchery - Oxford	Full Route	Yes
17	Cutteslowe - Oxford	No	Yes
18	Bampton - Oxford	No	Yes
20	UnipartHouse - RoseHill	No	Yes
21	Bicester - Chesterton -	Full Route	No
22	Bicester - Caversfield	Full Route	No
23	Bicester - Caversfield	Full Route	No
23 (Oxf)	Redbridge - John Radcliffe	Full Route	Yes
24	Bicester - Churchill Road	Full Route	No
25	Bicester - Kidlington	No	No
25A	Bicester - Oxford	Partial: Kirtlington - Oxford	No
26	Bicester - Kingsmere	Full Route	Yes
31	Wantage - Oxford	Partial: Abingdon - Oxford	Yes
32	Wantage - Abingdon	No	Yes
35	Abingdon - Oxford	No	Yes
36	Wallingford - Wantage	No	Yes
44	Abingdon - Oxford	Full Route	No
63	Southmoor - Oxford	No	No
66	Swindon - Oxford	Partial: Southmoor - Oxford	No
97	Didcot - Berinsfield	No	Yes
98	Didcot - Orchard Centre	Full Route	Yes
103	Little Milton - Oxford	No	No
104	Denton - Oxford	No	No
108	Forest Hill - Oxford	No	No
280	Oxford - Aylesbury	Partial: Oxford - Wheatley	No
300	Peartree - Redbridge (Park and Ride)	Full Route	Yes
400	Thornhill - Seacourt (Park and Ride)	Full Route	Yes
500	Water Eaton - Oxford (Park and Ride)	Full Route	Yes
700	Kidlington - Headington (Park and Ride)	Full Route	Yes
737	Oxford - Stansted Airport	No	No
800	Thornhill - John Radcliffe (Park and Ride)	Full Route	Yes
900	Thornhill - Headington (Park and Ride)	Full Route	Yes
LGW	Gatwick Airport - Oxford	No	Yes
LHR	Heathrow Airport - Oxford	No	Yes
M10	Milton Park - Didcot Parkway	Full Route	No
S1	Carterton - Oxford	Partial: Witney - Oxford	Yes
S2	Brize Norton - Oxford	Partial: Eynsham - Oxford	Yes
S3	Chipping Norton - Oxford	Partial: Woodstock - Oxford	Yes
S4	Banbury - Oxford	No	Yes
S5	Bicester - Oxford	Partial: Bicester Village - Oxford	Yes
T1	Watlington – Oxford	No	Yes
T2	Abingdon – Oxford	No	No
T3	Oxford Science Park - Oxford	Full Route	No

Service	Route	Survey	ETM
TUBE	London Victoria - Oxford	Partial: Oxford - Lewknor	Yes
U1	Harcourt Hill - Wheatley	Partial: Oxford - Wheatley Campus	Yes
U1B	Oxford – Wheatley	Full Route	Yes
U5	New Marston - Oxford	Full Route	Yes
U5X	Wheatley – Oxford	No	Yes
Bic Shuttle	Bicester Village Shuttle	Full Route	No
X2	Wallingford - Oxford	No	Yes
X3	Abingdon – Oxford	Full Route	Yes
X5	Oxford – Cambridge	Partial: Oxford - Bicester	No
X13	Abingdon - John Radcliffe	Partial: Abingdon - New Marsden	Yes
X30	Wantage – Oxford	Partial: East Hanney - Oxford	Yes
X32	Chilton – Oxford	No	Yes
X39	Reading – Oxford	No	Yes
X40	Reading – Oxford	No	Yes
X90	London Victoria - Oxford	No	Yes

5.2.1. Bus Survey Data

The 2013 onboard origin-destination surveys collected a range of data, including:

- the journey origin and destination;
- modes of access to and egress from the bus;
- journey purpose;
- whether the trip was part of a return journey, and the time of the other journey leg; and
- whether a P&R site was used.

Boarding and alighting counts were also conducted at each stop on the route. These were used to calculate expansion factors.

The data were processed by:

- a series of checks to correct transcription errors and remove any inconsistent records;
- coding trip origins and destinations to OSM zones, using the coordinates of the origin and destination postcodes;
- allocating trips to time periods;
- calculating expansion factors; and
- processing reverse direction trips.

Expansion Factors

Expansion factors were calculated for each surveyed bus service, taking account of:

- the bus sample rate: the proportion of timetabled bus services actually surveyed (by time period); and
- the interview sample rate: the proportion of passengers on each surveyed bus who completed the survey questionnaire.

Table 5-2 to Table 5-4 show the proportion of buses surveyed and the average overall expansion factors for each surveyed service by time period[2].

Table 5-2 AM Peak Expansion Factors

[2] The time periods referred to here are AM Peak Period (0700-1000), Inter Peak Period (1000-1600) and PM Peak Period (1600-1900).

Service	Direction	Bus Sample Rate	Interview Sample Rate	Overall Sample Rate	Expansion Factor
1	IB	35%	17%	6%	16.6
1	OB	52%	20%	11%	9.5
2	IB	58%	13%	8%	13.1
2	OB	67%	14%	9%	10.9
3	IB	26%	18%	5%	21.0
3	OB	41%	43%	17%	5.7
4	IB	28%	22%	6%	16.3
4	OB	26%	31%	8%	12.2
5	IB	17%	14%	2%	40.7
5	OB	24%	22%	5%	18.8
10	IB	28%	18%	5%	20.4
10	OB	47%	14%	6%	15.5
12	IB	33%	33%	11%	9.0
12	OB	50%	60%	30%	3.3
13	IB	33%	17%	6%	17.6
13	OB	40%	19%	8%	13.2
14	IB	133%	26%	35%	2.9
14	OB	100%	23%	23%	4.4
16	IB	29%	3%	1%	120.8
16	OB	60%	10%	6%	17.2
21	C	42%	59%	25%	4.1
22	C	50%	76%	38%	2.6
23 (Bic)	C	50%	42%	21%	4.8
23 (Oxf)	IB	0%	0%	0%	n/a
23 (Oxf)	OB	0%	0%	0%	n/a
24	C	25%	0%	0%	n/a
26	IB	0%	0%	0%	n/a
26	OB	0%	0%	0%	n/a
31	IB	50%	60%	30%	3.3
31	OB	33%	108%	36%	2.8
44	IB	67%	100%	67%	1.5
44	OB	100%	67%	67%	1.5
66	IB	11%	13%	1%	67.5
66	OB	12%	4%	0%	229.5
98	C	83%	67%	56%	1.8
280	IB	25%	29%	7%	13.7
280	OB	33%	19%	6%	15.9
300	IB	28%	24%	7%	14.8
300	OB	35%	20%	7%	14.4
400	IB	20%	21%	4%	23.7
400	OB	25%	29%	7%	13.7
500	IB	15%	24%	4%	26.9
500	OB	27%	60%	16%	6.1

Service	Direction	Bus Sample Rate	Interview Sample Rate	Overall Sample Rate	Expansion Factor
700	C	44%	17%	8%	13.3
800	IB	44%	71%	31%	3.2
800	OB	56%	67%	37%	2.7
900	IB	33%	38%	13%	7.9
900	OB	44%	50%	22%	4.5
25A	IB	0%	0%	0%	n/a
25A	OB	50%	44%	22%	4.5
Bic Shut	IB	43%	0%	0%	n/a
Bic Shut	OB	38%	12%	4%	22.4
M10	IB	43%	50%	21%	4.7
M10	OB	43%	6%	2%	40.7
S1	IB	21%	18%	4%	25.6
S1	OB	33%	21%	7%	14.3
S2	IB	0%	0%	0%	n/a
S2	OB	25%	33%	8%	12.0
S3	IB	10%	18%	2%	56.4
S3	OB	13%	36%	4%	22.4
S5	IB	13%	28%	3%	28.9
S5	OB	20%	24%	5%	20.6
T3	IB	40%	15%	6%	16.9
T3	OB	60%	35%	21%	4.8
Tube	IB	25%	7%	2%	54.0
Tube	OB	21%	23%	5%	20.3
U1	IB	38%	15%	6%	17.5
U1	OB	38%	2%	1%	129.1
U5	IB	0%	0%	0%	n/a
U5	OB	17%	5%	1%	132.0
X13	IB	30%	17%	5%	19.3
X13	OB	50%	17%	8%	11.8
X3	IB	19%	39%	7%	13.5
X3	OB	50%	39%	20%	5.1
X30	IB	0%	0%	0%	n/a
X30	OB	0%	0%	0%	n/a
X5	IB	17%	22%	4%	27.0
X5	OB	14%	83%	12%	8.4

Table 5-3 Inter Peak Expansion Factors

Service	Direction	Bus Sample Rate	Interview Sample Rate	Overall Sample Rate	Expansion Factor
1	IB	31%	13%	4%	25.0
1	OB	31%	12%	4%	27.7
2	IB	68%	14%	9%	10.6
2	OB	71%	13%	9%	11.1

Service	Direction	Bus Sample Rate	Interview Sample Rate	Overall Sample Rate	Expansion Factor
3	IB	23%	25%	6%	17.1
3	OB	24%	18%	4%	22.6
4	IB	17%	40%	7%	14.6
4	OB	35%	22%	8%	12.6
5	IB	11%	17%	2%	52.8
5	OB	13%	20%	3%	37.3
10	IB	23%	24%	5%	18.5
10	OB	23%	24%	6%	18.0
12	IB	33%	24%	8%	12.3
12	OB	25%	36%	9%	11.2
13	IB	39%	19%	7%	13.7
13	OB	39%	26%	10%	10.1
14	IB	50%	19%	10%	10.3
14	OB	67%	46%	30%	3.3
16	IB	67%	10%	7%	15.2
16	OB	29%	8%	2%	43.8
21	C	40%	34%	14%	7.3
22	C	71%	60%	43%	2.3
23 (Bic)	C	83%	41%	34%	2.9
23 (Oxf)	IB	40%	54%	22%	4.6
23 (Oxf)	OB	36%	34%	12%	8.1
24	C	92%	55%	50%	2.0
26	IB	17%	0%	0%	n/a
26	OB	25%	0%	0%	n/a
31	IB	33%	81%	27%	3.7
31	OB	33%	24%	8%	12.8
44	IB	150%	73%	109%	0.9
44	OB	100%	150%	150%	0.7
66	IB	15%	23%	4%	28.1
66	OB	15%	24%	4%	27.6
98	C	83%	68%	57%	1.8
280	IB	39%	22%	9%	11.6
280	OB	39%	22%	9%	11.5
300	IB	21%	30%	6%	16.5
300	OB	21%	12%	3%	39.3
400	IB	27%	38%	10%	9.9
400	OB	20%	36%	7%	13.8
500	IB	25%	26%	7%	15.2
500	OB	24%	22%	5%	19.0
700	C	33%	20%	7%	14.8
800	IB	44%	67%	30%	3.4
800	OB	39%	8%	3%	30.9
900	IB	39%	0%	0%	n/a

Service	Direction	Bus Sample Rate	Interview Sample Rate	Overall Sample Rate	Expansion Factor
900	OB	39%	29%	11%	9.0
25A	IB	57%	54%	31%	3.3
25A	OB	67%	42%	28%	3.5
Bic Shut	IB	61%	12%	7%	13.7
Bic Shut	OB	67%	14%	9%	10.8
M10	IB	21%	0%	0%	n/a
M10	OB	29%	40%	11%	8.8
S1	IB	33%	27%	9%	11.1
S1	OB	43%	16%	7%	14.4
S2	IB	33%	19%	6%	15.5
S2	OB	33%	26%	9%	11.5
S3	IB	31%	9%	3%	35.3
S3	OB	33%	15%	5%	20.4
S5	IB	29%	27%	8%	12.9
S5	OB	21%	19%	4%	25.3
T3	IB	83%	11%	9%	11.4
T3	OB	83%	20%	17%	6.0
Tube	IB	33%	21%	7%	14.1
Tube	OB	35%	16%	6%	17.9
U1	IB	33%	6%	2%	50.2
U1	OB	45%	1%	1%	167.9
U5	IB	55%	9%	5%	19.8
U5	OB	50%	11%	5%	18.8
X13	IB	33%	23%	8%	12.8
X13	OB	32%	11%	3%	29.9
X3	IB	50%	42%	21%	4.7
X3	OB	50%	23%	11%	8.7
X30	IB	25%	24%	6%	16.9
X30	OB	27%	39%	11%	9.3
X5	IB	17%	9%	1%	70.5
X5	OB	33%	50%	17%	6.0

Table 5-4 PM Peak Expansion Factors

Service	Direction	Bus Sample Rate	Interview Sample Rate	Overall Sample Rate	Expansion Factor
1	IB	23%	20%	5%	22.0
1	OB	18%	30%	5%	18.4
2	IB	67%	18%	12%	8.3
2	OB	58%	6%	3%	30.9
3	IB	45%	27%	12%	8.1
3	OB	36%	16%	6%	17.5
4	IB	41%	16%	7%	14.9
4	OB	31%	10%	3%	31.4

Service	Direction	Bus Sample Rate	Interview Sample Rate	Overall Sample Rate	Expansion Factor
5	IB	23%	6%	1%	67.8
5	OB	13%	17%	2%	45.5
10	IB	40%	8%	3%	29.6
10	OB	21%	17%	4%	28.3
12	IB	33%	8%	3%	39.0
12	OB	33%	2%	1%	127.5
13	IB	63%	23%	15%	6.8
13	OB	38%	19%	7%	14.0
14	IB	133%	16%	21%	4.8
14	OB	67%	35%	23%	4.3
16	IB	33%	20%	7%	15.0
16	OB	33%	16%	5%	18.8
21	C	50%	37%	18%	5.5
22	C	67%	64%	42%	2.4
23 (Bic)	C	67%	33%	22%	4.5
23 (Oxf)	IB	0%	0%	0%	n/a
23 (Oxf)	OB	0%	0%	0%	n/a
24	C	83%	0%	0%	n/a
26	IB	100%	100%	100%	1.0
26	OB	100%	100%	100%	1.0
31	IB	33%	18%	6%	16.5
31	OB	67%	30%	20%	4.9
44	IB	100%	43%	43%	2.3
44	OB	50%	67%	33%	3.0
66	IB	25%	21%	5%	19.1
66	OB	18%	12%	2%	48.7
98	C	90%	39%	35%	2.8
280	IB	50%	18%	9%	11.1
280	OB	57%	13%	7%	13.9
300	IB	38%	14%	5%	19.1
300	OB	29%	13%	4%	26.3
400	IB	21%	20%	4%	23.0
400	OB	21%	29%	6%	16.1
500	IB	31%	41%	13%	7.9
500	OB	25%	20%	5%	19.6
700	C	38%	21%	8%	12.7
800	IB	50%	63%	31%	3.2
800	OB	50%	75%	38%	2.7
900	IB	50%	0%	0%	n/a
900	OB	38%	32%	12%	8.3
25A	IB	67%	26%	18%	5.7
25A	OB	20%	23%	5%	21.7
Bic Shut	IB	72%	8%	6%	16.5

Service	Direction	Bus Sample Rate	Interview Sample Rate	Overall Sample Rate	Expansion Factor
Bic Shut	OB	61%	71%	44%	2.3
M10	IB	42%	8%	3%	29.5
M10	OB	42%	5%	2%	52.8
S1	IB	40%	19%	8%	13.3
S1	OB	31%	15%	5%	21.5
S2	IB	20%	40%	8%	12.5
S2	OB	0%	0%	0%	n/a
S3	IB	29%	21%	6%	16.5
S3	OB	29%	14%	4%	24.9
S5	IB	30%	20%	6%	16.7
S5	OB	14%	10%	1%	68.5
T3	IB	40%	9%	3%	29.2
T3	OB	20%	0%	0%	n/a
Tube	IB	42%	12%	5%	20.7
Tube	OB	23%	13%	3%	32.3
U1	IB	100%	3%	3%	34.7
U1	OB	50%	3%	2%	64.7
U5	IB	50%	18%	9%	11.4
U5	OB	33%	8%	3%	37.5
X13	IB	50%	10%	5%	19.5
X13	OB	30%	18%	5%	18.8
X3	IB	56%	40%	22%	4.5
X3	OB	19%	17%	3%	31.4
X30	IB	50%	41%	21%	4.9
X30	OB	17%	0%	0%	n/a
X5	IB	17%	23%	4%	26.0
X5	OB	17%	20%	3%	30.0

The overall sample rates that were achieved for many of the services were quite low, so expansion factors are consequently high. For services for which only a very limited amount of origin-destination records were collected, the data were aggregated across the whole day in order to obtain a more reasonable distribution of trips. The trips were subsequently allocated to time periods using factors calculated from the passenger counts. The services for which an all-day distribution was used, along with the corresponding time period factors, are shown in Table 5.5.

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Table 5-5 Services for which an all-day distribution was used

Service	Direction	AM Factor	IP Factor	PM Factor
16	IB	0.55	0.24	0.21
16	OB	0.11	0.39	0.50
22	C	0.24	0.65	0.11
23	C	0.22	0.61	0.17
25A	IB	0.28	0.47	0.25
25A	OB	0.21	0.34	0.45
26	IB	0.28	0.47	0.25
26	OB	0.28	0.47	0.25
31	IB	0.24	0.50	0.26
31	OB	0.28	0.54	0.18
4	IB	0.70	0.24	0.06
4	OB	0.16	0.74	0.10
44	IB	0.34	0.34	0.32
44	OB	0.43	0.14	0.43
66	IB	0.28	0.47	0.25
66	OB	0.28	0.47	0.25
800	IB	0.40	0.43	0.17
800	OB	0.10	0.59	0.31
900	IB	0.44	0.32	0.24
900	OB	0.10	0.40	0.50
Bicester shuttle	IB	0.01	0.51	0.48
Bicester shuttle	OB	0.17	0.79	0.04
M10	IB	0.03	0.08	0.89
M10	OB	0.90	0.02	0.07
S2	IB	0.28	0.47	0.25
S2	OB	0.28	0.47	0.25
S3	IB	0.28	0.47	0.25
S3	OB	0.28	0.47	0.25
S5	IB	0.28	0.47	0.25
S5	OB	0.28	0.47	0.25
T3	IB	0.46	0.24	0.30
T3	OB	0.42	0.27	0.31
U1	IB	0.22	0.50	0.28
U1	OB	0.42	0.33	0.25
U5	IB	0.28	0.47	0.25
U5	OB	0.31	0.39	0.30
X30	IB	0.28	0.47	0.25
X30	OB	0.28	0.47	0.25
X5	IB	0.31	0.54	0.15
X5	OB	0.28	0.47	0.25

It should be noted that the impact of trip estimates derived from high expansion factors on the final matrices is mitigated by the use of a variance weighting technique to combine the observed data with the ETM data.

This gives less prominence to data points derived from large expansion factors – see Section 5.3.1 for more details.

Reverse Direction Trips

The survey included a question on whether the bus journey was part of an identical return trip, and what time the other leg of the journey was made. The non-interview direction trips were used to boost the sample size and produce a more robust distribution.

The non-interview direction trips were processed by interchanging the origin and destination and allocating to the reverse trip time period. They were then added to the dataset and the expansion factors were adjusted to control to the total boardings per service in each time period.

Preparation of Bus Survey Matrices

The survey records were classified according to:

- time period (AM Peak Period 07:00 – 10:00; Inter Peak Period 10:00 – 16:00; PM Peak Period 16:00 – 19:00);
- trip type: whether it was a P&R trip, “bus-rail” trip or “bus-only” trip (see below); and
- whether ETM data was available for the surveyed route.

Using this classification, the records were split into 18 separate matrices (by time period, trip type and ETM availability).

Park-and-Ride Trips

The following bus services were classified as “P&R services”:

- 300 Peartree - Redbridge
- 400 Thornhill - Seacourt
- 500 Water Eaton - Oxford
- 700 Kidlington - Headington
- 800 Thornhill - John Radcliffe
- 900 Thornhill - Headington
- 23 Redbridge - John Radcliffe

Records were classified as P&R if:

- one of the P&R services listed above was used; and
- the respondent reported parking at a P&R site.

Note that in the OSM the P&R mode only includes trips to Oxford city centre using one of the five P&R sites located on the edge of Oxford. Travellers parking at Thornhill P&R site and getting on a longer-distance coach to London or one of the airports are not included within the definition of P&R. Passengers that board a bus at a P&R site but have not parked are also not considered to be P&R passengers.

Bus-Rail Trips

Trips using rail as their mode of access to the bus stop or onwards mode to their final destination were classified as “bus-rail” trips. Due to the hierarchical definition of public transport trips that has been adopted for the OSM, these journeys are included in the rail mode and not the bus mode. The matrices of multi-modal bus-rail trips were therefore merged into the OSM rail matrices – see Section 5.6 for more details.

Bus-Only Trips

The “bus-only” matrices consisted of all trips that were not classified as P&R or “bus-rail”.

Multi-stage Bus Trips

While there were a number of trips using bus as their mode of access to the bus stop or onwards mode to their final destination, only a small proportion of them reported having transferred to or from another surveyed service, so the amount of possible double-counting of bus trips was small, and therefore no action was taken to correct for this.

5.2.2. ETM data

Fare stage to fare stage matrices

Electronic Ticket Machines record the tickets purchased by passengers, giving a matrix of "fare-paying" trips on a fare stage to fare stage basis. They also record the origin fare stage of "non-fare-paying trips" (e.g. season ticket journeys, return leg of return journeys, etc.).

The ETM data were processed to:

- calculate average weekday trips and allocate trip records to time periods; and
- allocate the non-fare-paying trips (from each origin fare stage) to destination fare stages based on the distribution of fare-paying trips from that origin.

This method of allocating the non-fare-paying trips to destinations assumes that the distributions of fare-paying and non-fare-paying trips are the same. This may not be a reasonable assumption in all cases. In particular, the proportion of non-fare-paying trips is high in the PM Peak, when most journeys are the return legs of outbound trips made earlier in the day. Checks were undertaken comparing the output PM Peak matrices against the transpose of the equivalent AM Peak matrices. In most cases, the distributions were similar, indicating that the assumption was reasonable.

An exception was the Oxford to London coach services (X90 and Oxford Tube). The pattern of trips was quite different for tickets purchased in London and tickets purchased in Oxfordshire:

- Almost all passengers buying tickets in London were going to Oxford city centre.
- More than half of the passengers buying tickets at the Oxford end started their journey outside the city centre (in Headington or at the Thornhill P&R site).

The distribution of fare-paying trips from London was therefore not appropriate for non-fare-paying passengers returning to Oxford. The distribution was therefore adjusted on the based on boarding and alighting counts for the Oxford Tube service.

Allocation of fare stages to OSM zones

A correspondence was prepared to allocate fare stages to OSM zones.

Within Oxfordshire, GIS was used to select all zone centroids within a certain radius of each fare stage:

- in urban areas, zone centroids within 500m of the fare stage were selected;
- in rural areas, zone centroids within 1km of the fare stage were selected; and
- if no zone centroids were found within the specified radius, the closest zone was selected.

For P&R fare stages, the demand was distributed among all of the zones within the catchment area of the P&R site (see Section 5.4 on P&R matrices below).

Factors were calculated to distribute the trips between the zones allocated to each fare stage. These factors were based on:

- the distance of the zone from the nearest bus stop included in the fare stage; and
- zonal population from the 2011 census (the maximum of the "daytime population" and the "resident population" was used in order to take account of zones containing employment but only limited amounts of housing).

In the hinterland and external areas, bus fare stages were simply allocated to the zone containing them.

Preparation of ETM Matrices

Zonal matrices were produced by applying the fare stage to zone correspondence to the fare stage matrices.

Separate matrices were the produced for:

- each time period;
- each trip type: P&R, "bus-rail" or "bus-only" (see below); and

- surveyed and non-surveyed routes (N.B. for routes that were only partially surveyed, only the fare-stage to fare-stage movements that were captured by the survey were included in the "surveyed routes" matrices)

ETM Park & Ride Trips

The survey data was analysed to determine what proportion of passengers boarding and alighting at P&R sites are P&R passengers (i.e. have parked their car at the site). These proportions are presented in Table 5-6. The corresponding proportions of trips to and from the P&R fare stages were classified as P&R trips and included in the P&R matrices.

Table 5-6 Proportion of Boarders/Alighters at P&R Sites that are P&R Passengers

Site	Fare Stage Code	Proportion
Thornhill	102147	0.867
Redbridge	100075	0.986
Water Eaton	101090	0.968
Peartree	102115	0.997
Seacourt	101071	0.921

ETM Bus-Rail Trips

The survey data was analysed to determine what proportion of passengers boarding and alighting a bus at a rail station have transferred from a rail service. These proportions are presented in Table 5-7. The corresponding proportions of trips to and from the rail station fare stages were classified as bus-rail trips and included in the bus-rail matrices.

Note that ETM data was not available for local bus services in Bicester (so there were no bus-rail trips interchanging at Bicester in the dataset) and interchanges were not considered for smaller stations in Oxfordshire because they were expected to be very low volume.

Table 5-7 Proportion of Bus Boarders/Alighters at Rail Stations that have Transferred from Rail

Site	Proportion
Oxford	0.6
Didcot Parkway	0.8

The ETM bus-rail trips were not actually used in the matrix-building process, but it was important to identify them in order to exclude them from the bus-only matrices.

ETM Bus-Only Trips

The bus-only trip matrices were derived by subtracting the P&R and bus-rail trips.

5.3. Bus-Only Matrices

This section describes the steps taken to produce the final bus-only matrices, by merging the two data sources. The production of P&R matrices is covered in the next section.

5.3.1. Merging Data from Surveys and Ticket Records

The observed onboard origin-destination survey and ETM matrices were merged by variance weighting. Each data source has its own particular strengths and weaknesses:

- The survey matrices give the best indication of true origins and destinations, but relate to a single day, and are derived from a sample of trips such that each recorded trip is assumed to represent a number of actual trips (how many is governed by the expansion factor). This results in a "lumpy" matrix distribution whereby the demand is concentrated among an arbitrary subset of the true set of origins and destinations.

- The ETM matrices are based on average trip making over a four week period and (in principle) include all trips rather than just a sample. However, various approximations have been required to convert from fare stage to true origin-destination. In some respects, the ETM matrices can be considered “synthetic” because the trips to/from each stage have been spread synthetically among appropriate origin and destination zones. This means that the ETM matrices are “smooth”, as opposed to the “lumpy” survey matrices.

The following steps were carried out to merge the survey and ETM matrices:

- combine ETM data for surveyed routes with the survey data using variance weighting techniques;
- control demand to ETM totals at the sector-sector level; and
- add in ETM demand for non-surveyed routes and survey data for routes for which there is no ETM dataset.

Variance Weighting

The two sources of demand data were combined using variance weighting to give output matrices that make use of the most reliable estimates of demand for each origin-destination pair.

The ETM and observed matrices were combined on a cell by cell basis using a weighted average. Thus for cell i,j:

$$M_{ij} = \frac{I_{ij}^{S} E_{ij} + I_{ij}^{E} S_{ij}}{I_{ij}^{S} + I_{ij}^{E}} \qquad (1)$$

where: M_{ij} = Merged matrix

E_{ij} = ETM matrix

S_{ij} = Survey matrix

I_{ij}^{E} = Index of dispersion matrix for Wayfarer data

I_{ij}^{S} = Index of dispersion matrix for Observed data

and the Index of dispersion I_{ij} is a function of the variance of the trip estimate:

$$I_{ij} = Var(T_{ij}) / T_{ij} \qquad (2)$$

Variance of Trip Estimate for Survey Data

For the survey data, the variance of the trip estimate may be calculated directly:

$$Var(T_{ij}) = \sum_{n} e_{ij}(e_{ij} - 1) \qquad (3)$$

where: e is the expansion factor for each recorded journey;

n is the number of recorded journeys from origin i to destination j; and

$T_{ij} = \sum_{n} e_{ij}$ is the total number of trips for cell ij.

Notes on the calculation of variances:

a. For services for which an all-day distribution was derived (see above), the value of e(e-1) obtained was doubled to reflect the added uncertainty in the trip estimate.

b. For non-interview direction trips, the value of e(e-1) obtained was doubled to reflect the added uncertainty in the trip estimate.

Variance of Trip Estimate for the ETM Data

For the ETM data, the variance could not be calculated directly in the same way as for the survey data. The survey data were analysed to find a relationship between the demand estimate (T_{ij}) and the variance Var(T_{ij}), as shown in Figure 5-1[3].

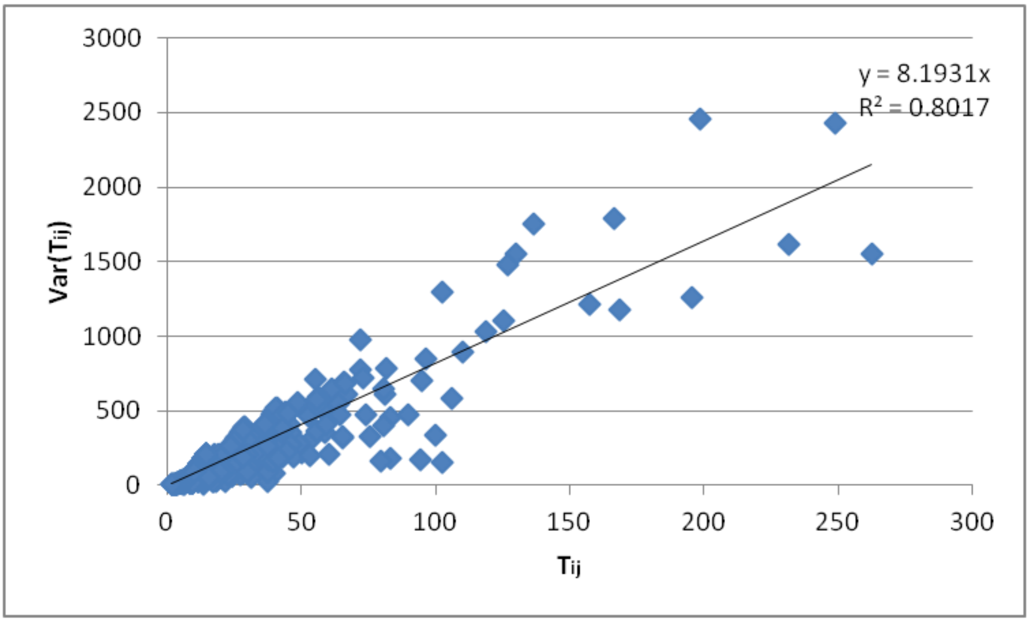


Figure 5-1 Regression analysis of Tij and Var(Tij)

The function Var(T_{ij}) = 8.1931T_{ij} was then used to estimate variances for the ETM data based on the ETM demand for each ij pair, where T_{ij} is the all-day ETM demand.

Index of Dispersion Calculation

The index of dispersion was calculated for both survey and ETM data using equation (2) above. The ETM index of dispersion was a constant 8.1931, whereas the survey matrix index of dispersion values ranged between 0 and 285.

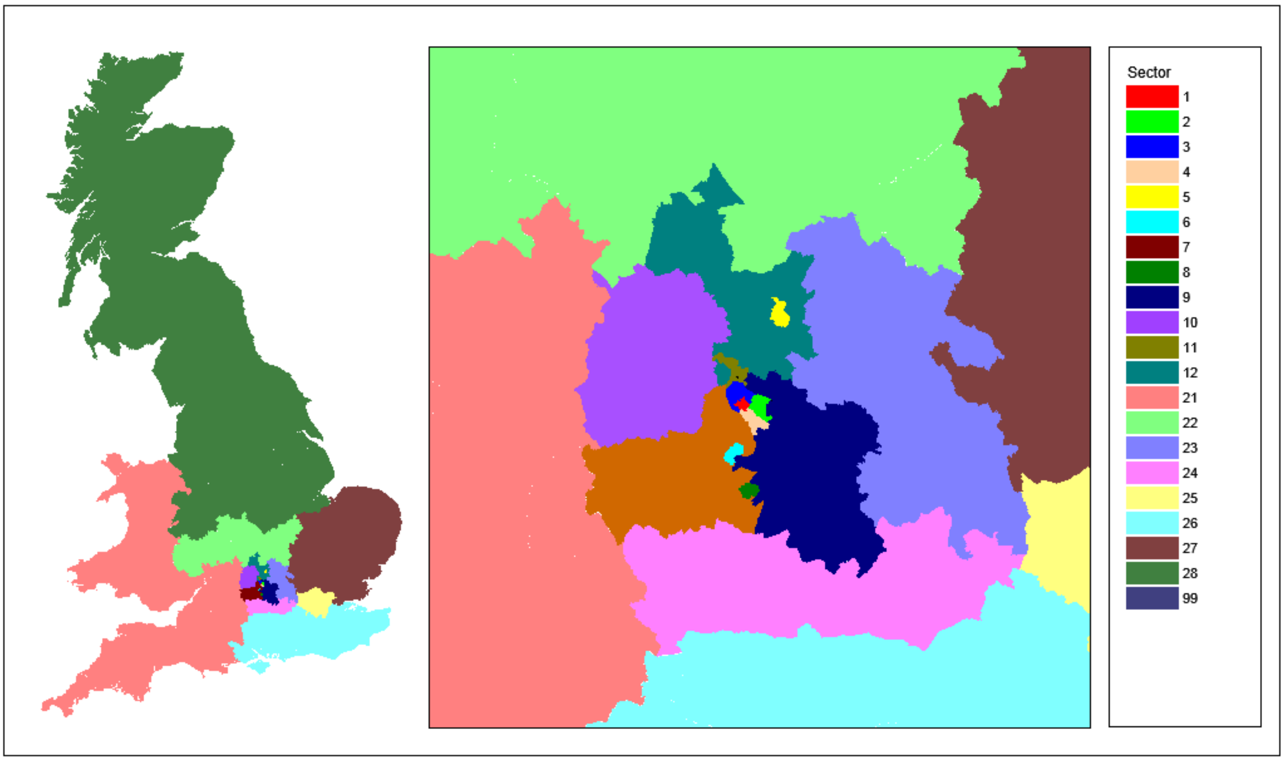
Where there were no trips in the survey matrices, the index of dispersion was set to 100.0, while for zero cells in the ETM matrix, it was set to 20.0.

Control Sector-Sector Movements

The merging process causes changes in the number of trips in the matrix for each time period. To deal with this, the matrices were factored to retain the ETM demand estimates on a sector-sector basis[4]. The sectors used are shown in Figure 5-2.

[3] This analysis is based on survey records with an expansion factor of less than 15.
[4] Due to the large expansion factors for many of the survey records, and the fact that the ETM data are an average across a whole month, the ETM dataset was considered more reliable on a sector to sector basis.

Figure 5-2 Sector System for OSM Bus Matrix Development



5.3.2. Comparison of Observed, ETM and Merged Matrices

Figure 5-3 to Figure 5-5 show trips to selected city centre zones in the AM peak observed, ETM and merged matrices respectively. The figures illustrate how the merging process smoothes the survey demand over a greater range of origins and destinations than are found in the survey matrix, while still retaining the observed pattern of trips. Nevertheless, the merged matrices are in general more similar to the ETM matrices. This is due to the relatively greater weighting given to ETM data in the variance weighting process.

Figure 5-3 AM Peak Trips to a City Centre Zone - Survey Matrix

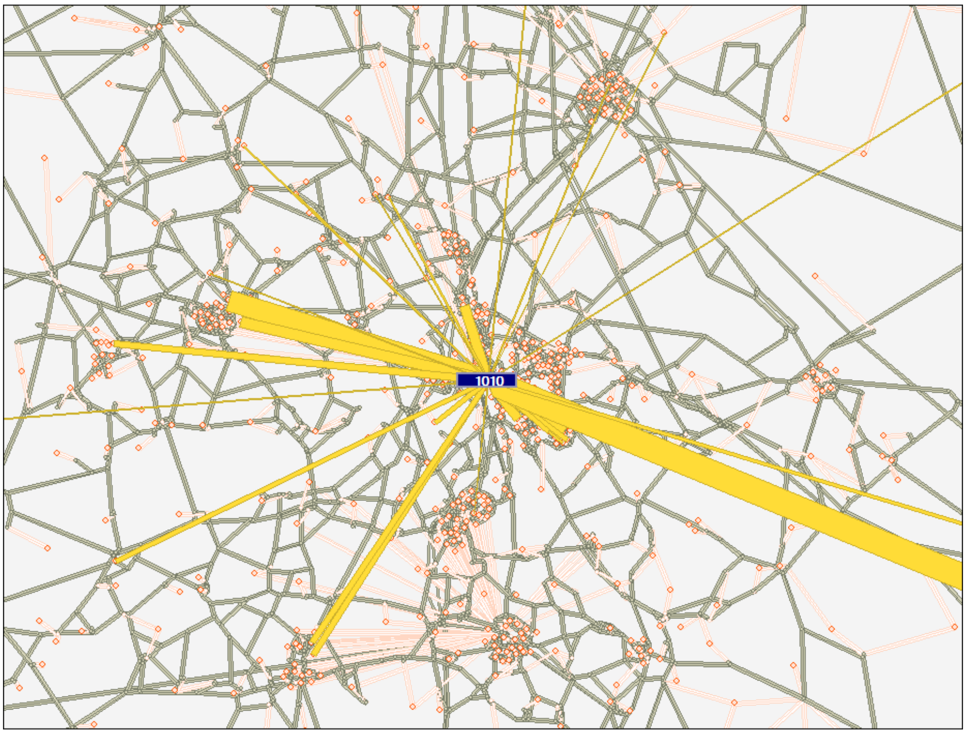


Figure 5-4 AM Peak Trips to a City Centre Zone - ETM Matrix

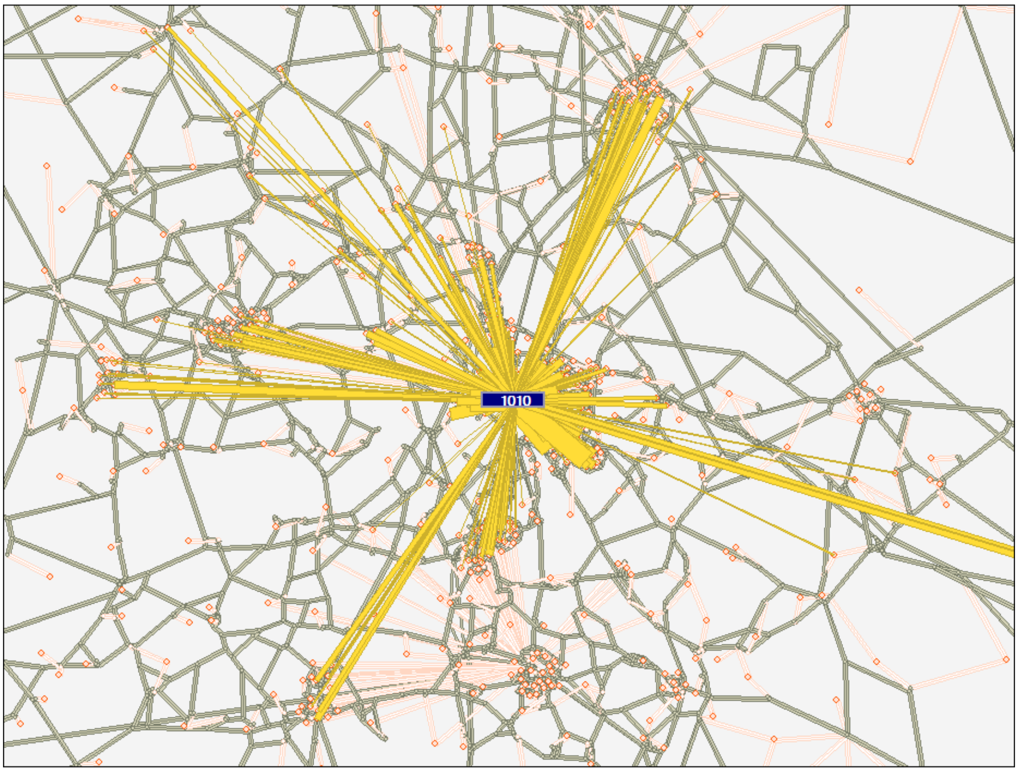
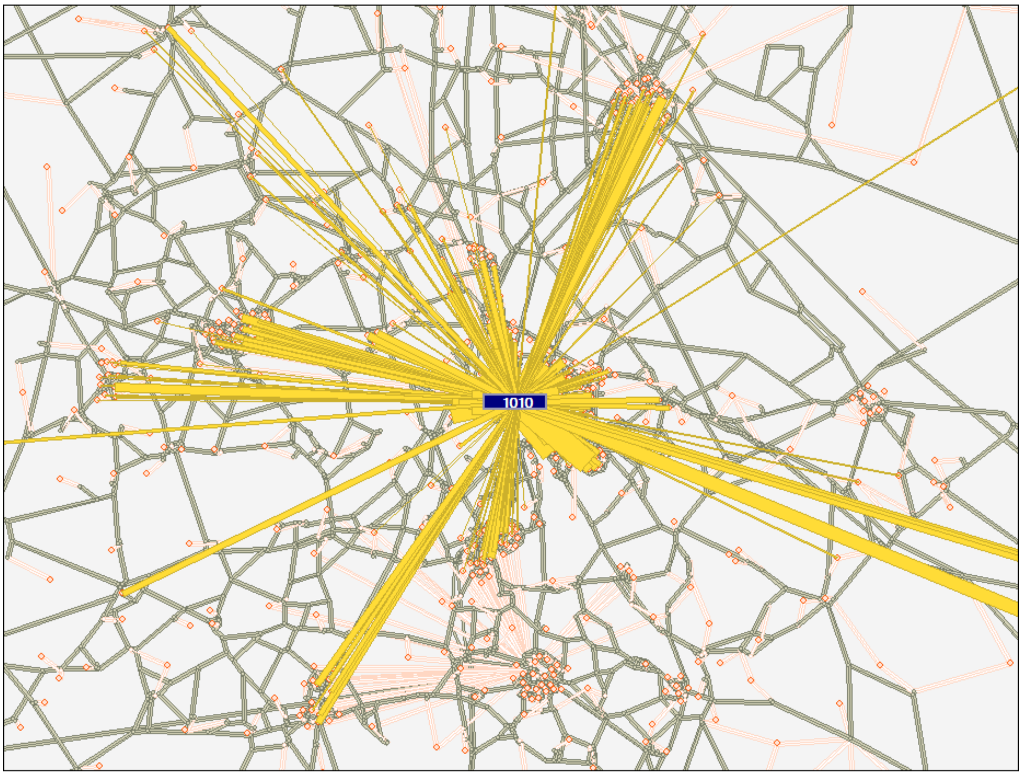


Figure 5-5 AM Peak Trips to a City Centre Zone - Merged Matrix



5.3.3. Full Bus-Only Demand Matrices

Full matrices were produced by adding together:

- the merged matrices (for routes where both ETM and survey data was available);
- ETM matrices for routes for which no survey was conducted; and

- survey matrices for routes for which ETM data was not available.

Peak period demand was then converted to hourly demand for assignment. Analysis of the survey count data indicated that peak period to peak hour factors varied across the study area, with a tendency for a lower proportion of AM peak hour (08:00 – 09:00) trips for longer-distance movements than for journeys within Oxford. There was less difference in PM peak factors for different movements. The factors used to convert from peak periods to hourly demand are presented in Table 5-8.

Table 5-8 Peak Period to Peak Hour Factors

Movement	AM Factor	IP Factor	PM Factor
Within Oxford	2.35	6	2.73
Bicester to Oxford	4.96	6	2.70
Oxford to Bicester	2.30	6	2.60
Rest of Oxfordshire to Oxford	3.35	6	2.70
Oxford to Rest of Oxfordshire	2.30	6	2.60
External to Oxford	3.02	6	2.77
Oxford to External	3.33	6	2.86
Other	2.76	6	2.68

5.3.4. Matrix Characteristics

Table 5-9 shows the matrix totals for each stage in the matrix building process.

Table 5-9 Bus Matrix Totals

Matrix building stage	AM Peak Period	Inter Peak Period	PM Peak Period
Surveyed Matrix	19,227	29,302	15,797
ETM Matrix	16,985	29,481	17,923
Merged Matrix (Surveyed+ETM)	21,123	33,879	20,474
Factored Merged Matrix	16,985	29,481	17,923
Full Matrix	27,925	46,839	27,885
	AM Peak Hour	**Inter Peak Average Hour**	**PM Peak Hour**
Hourly Bus-Only Matrix	10,688	7,807	10,306

Figure 5-6 to Figure 5-8 show the trip length distribution of the bus demand matrix at each stage in the process. It can be seen that the ETM matrices contain more short trips than the surveyed matrices.

The average journey lengths for each matrix are shown in Table 5-10. This confirms that the ETM matrices for the surveyed routes have a shorter trip distribution than the survey data for equivalent routes. This could be due to:

- the fact that the survey picks up the origin and destination of the full journey, including any interchanges, whereas the ETM records each journey leg separately; and/or
- the methodology adopted to allocate trips from fare stages to zones; and/ or
- a sampling bias whereby passengers on longer journeys are more likely to complete the survey questionnaire; and/or
- a bias in the ETM data due to the exclusion of full destination information for season and other pre-paid tickets.

It can be seen that the step to produce the full matrix adds longer-distance trips (> 50km). This is due to several long-distance routes, such as the airport services and the X5 from Oxford to Cambridge, being added at this stage.

Table 5-10 Average Journey Lengths

Matrix building stage	AM Peak Period	Inter Peak Period	PM Peak Period
Surveyed Matrix	14.86	12.63	13.41
ETM Matrix	9.73	9.07	10.59
Merged Matrix (Surveyed + ETM)	11.76	10.62	11.93
Factored Merged Matrix	10.07	9.38	11.06
Full Matrix	12.83	12.54	13.09

Figure 5-6 AM Peak Bus Trip Length Distribution Comparison

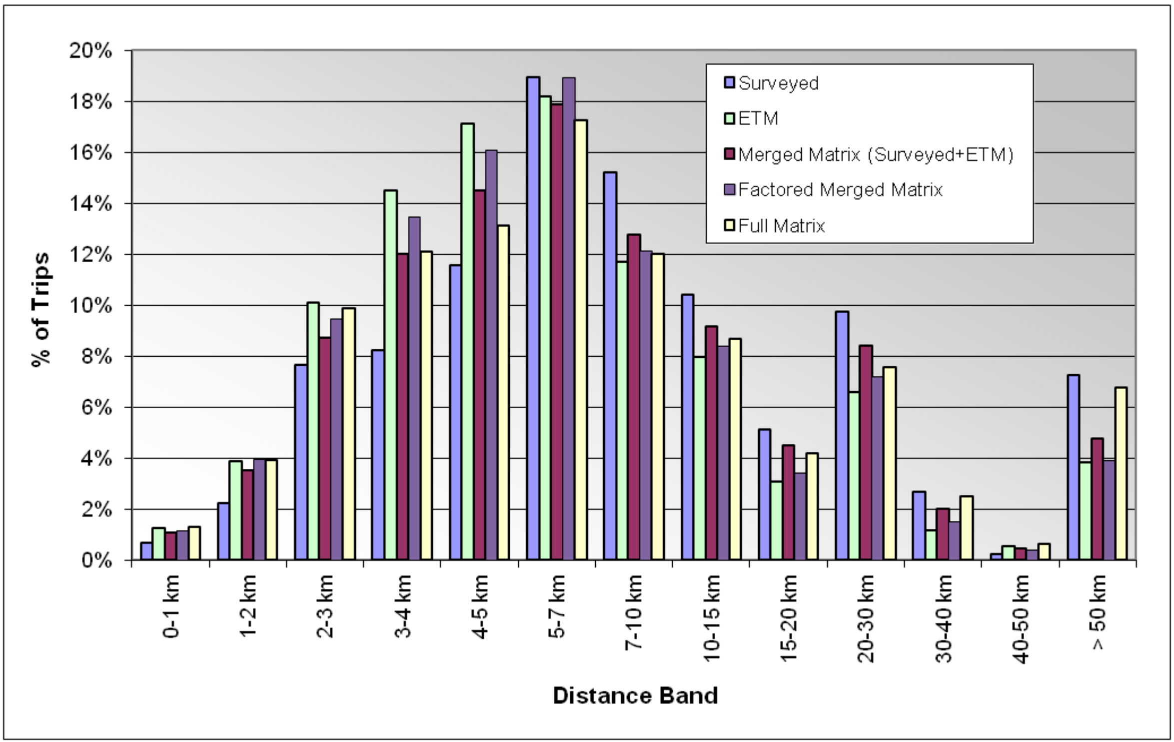


Figure 5-7 Inter Peak Bus Trip Length Distribution Comparison

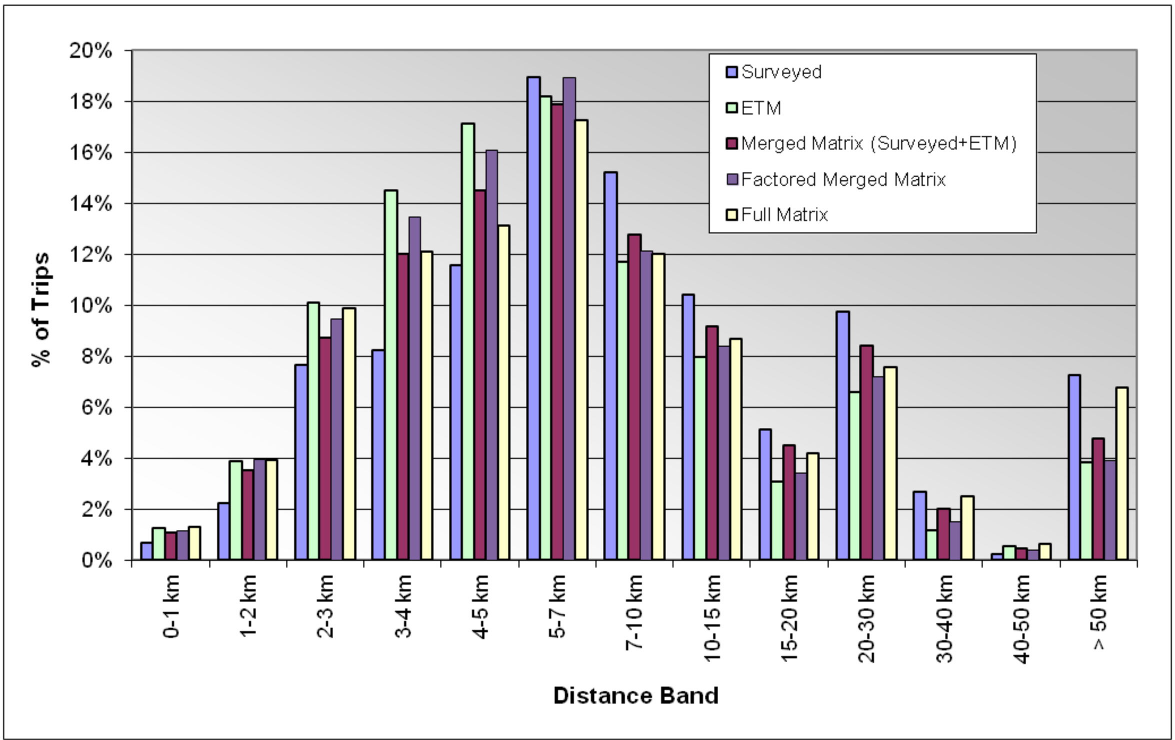
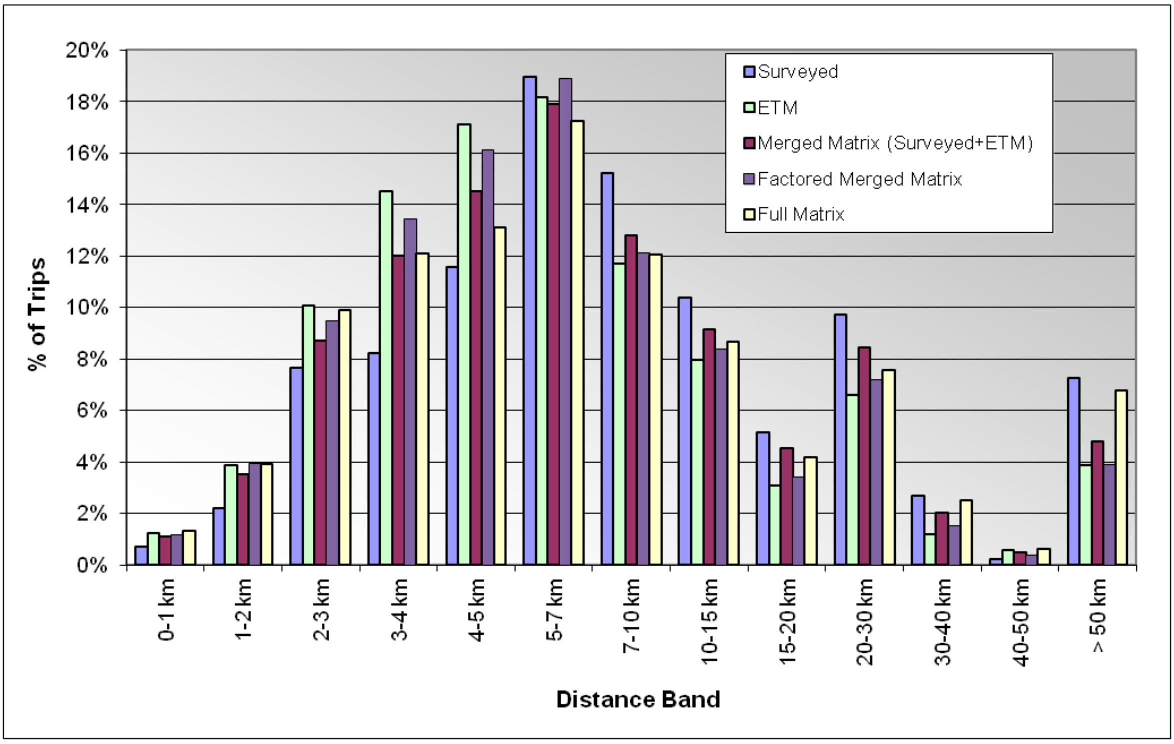


Figure 5-8 PM Peak Bus Trip Length Distribution Comparison



5.4. Park & Ride Matrices

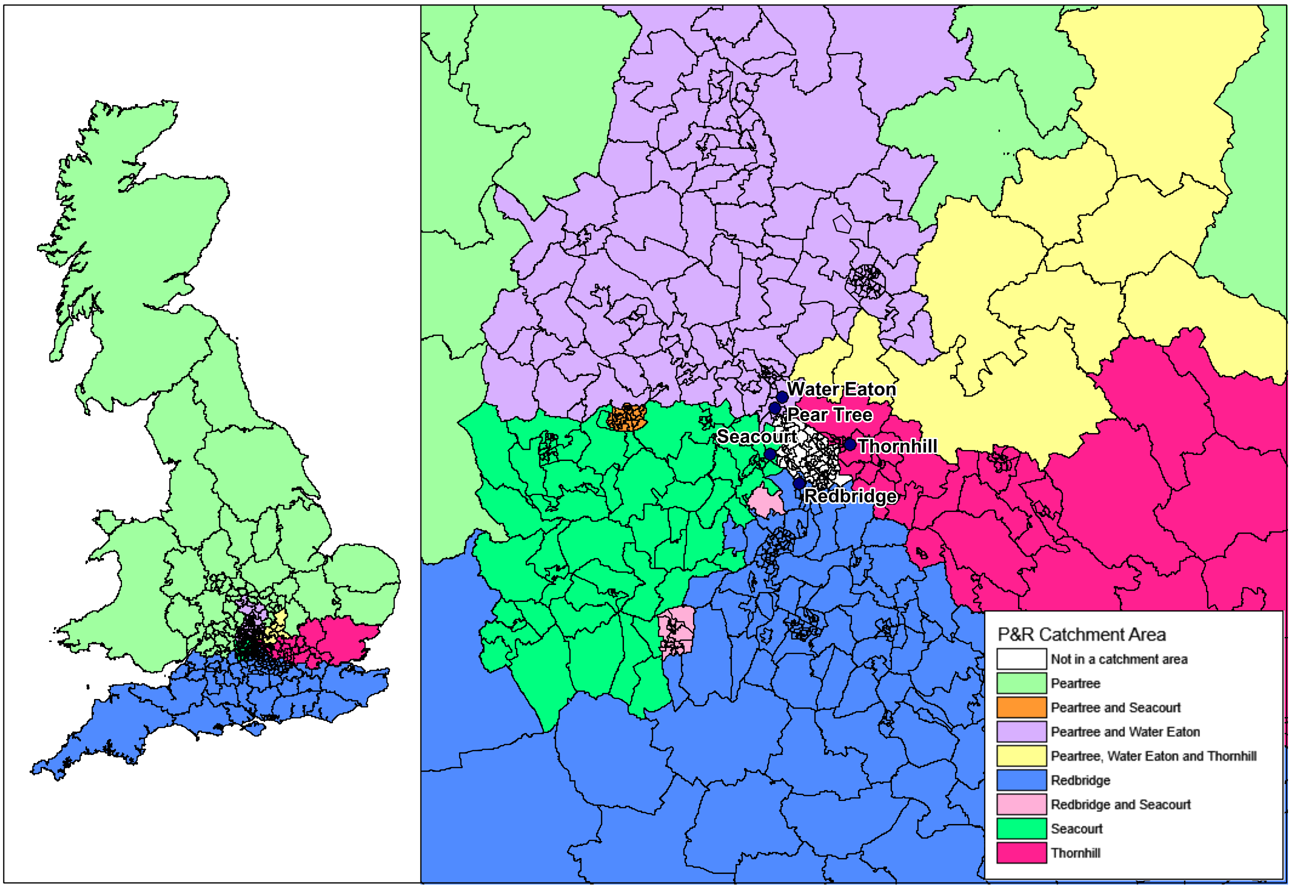
5.4.1. P&R Catchment Areas

There are five P&R sites located around the edge of the Oxford urban area:

- Peartree;
- Seacourt;
- Water Eaton;
- Thornhill; and
- Redbridge

The bus origin-destination survey data were analysed to derive a catchment area for each P&R site. All zones outside of Oxford were allocated to the catchment area of at least one P&R site. Some zones fall within the catchment area of two or more sites. The Peartree and Water Eaton sites are very close together, so there is a large degree of overlap between their catchment areas. The P&R sites and their catchment areas are shown in Figure 5-9.

Figure 5-9 P&R Catchment Areas



5.4.2. Processing ETM and Survey Data

ETM Data

The ETM data for P&R services required special treatment as the datasets contained several anomalies:

- Routes 300 and 400 go across Oxford, serving two P&R sites each. Some trips were allocated to the fare stage “250 - P R Pk Rtn”, which could refer to either P&R site.
- Many trips were recorded as going from one P&R site to the other. Analysis of the survey data indicated that in reality only a very small proportion of passengers would make these cross-Oxford movements.

The anomalous trip records were redistributed on the basis of the “valid” records in the dataset.

For P&R fare stages (corresponding to the Peartree, Seacourt, Water Eaton, Thornhill and Redbridge P&R sites), a fare stage to zone correspondence was produced to distribute trips among the zones within the catchment area for each site (see Figure 5-9). The distribution is based on:

- the distance of the zone from the P&R site (based on broad distance bands);
- zonal population from the 2011 census (the maximum of the "daytime population" and the “resident population” was used in order to take account of zones containing employment but only limited amounts of housing); and
- the surveyed distribution of trips using the P&R site (on a sector basis).

Survey Data

In the origin-destination survey, some respondents gave their origin or destination as the P&R site. These trips were redistributed based on the distribution of other trips using that site.

5.4.3. Comparison of Data Sources

In addition to the ETM and origin-destination survey data, information on P&R movements was available from Automatic Traffic Counts of cars entering and leaving each P&R site. Flows in and out of the sites were calculated by time period for an average weekday[5].

A comparison of the three data sources is presented in Table 5-11.

Table 5-11 Comparison of P&R Data

	Car Park Counts		ETM Data		Board/Alight Counts		O-D Survey
	Arrivals	Departures	Boardings	Alightings	Boardings	Alightings	Parked at Site
Peartree							
AM Peak	378	0	434	21	507	36	
Inter Peak	265	197	417	171	522	366	
PM Peak	27	374	78	219	48	389	
All day	669	571	930	411	1076	791	959
Redbridge							
AM Peak	514	12	515	19	591	32	
Inter Peak	314	315	450	214	615	728	
PM Peak	47	494	65	267	30	420	
All day	874	822	1030	500	1236	1180	1038
Water Eaton							
AM Peak	453	19	423	8	552	5	
Inter Peak	241	253	306	177	297	407	
PM Peak	25	453	20	193	13	393	
All day	720	725	749	378	862	805	1185
Seacourt							
AM Peak	434	9	278	7	375	20	
Inter Peak	122	145	161	109	206	215	
PM Peak	12	396	26	159	19	289	
All day	568	550	466	275	600	524	408
Thornhill							
AM Peak	543	144	598	64	571	58	
Inter Peak	402	404	420	265	484	375	
PM Peak	177	531	129	547	82	551	
All day	1122	1078	1147	875	1137	984	676

When comparing the data sources, various issues need to be taken into account:

- The origin-destination survey and associated boarding and alighting counts were conducted in November 2013. Peak demand for P&R occurs on weekdays in November, when Christmas shopping combines with commuting and work trips. The survey is therefore likely to give an overestimate of demand in an average month.
- ETM data for the principal P&R services (300, 400 and 500) are from April 2013, a neutral month. Data for services 700, 800 and 900 are from November 2013, but as these routes serve the Oxford hospitals rather than the city centre, the demand is not affected by Christmas shopping in November. The car park entry and exit data is also for a neutral month.

[5] Based on an average over the period 01/04/2012 – 31/03/2012 for the Thornhill site, and an average across April 2013 for the other four sites.

- As already noted, the high expansion factors as well as the fact that data were collected on only one or two days mean that there is a lower level of confidence in the survey data than the other two sources.
- The adjustments that were required to the ETM data (see above) mean that there is a degree of uncertainty in the ETM boardings and alightings. Across the whole day, the number of alightings at the P&R sites is less than indicated by the car park data. This could be because not all return trips were recorded by the ETM or due to an inaccurate distribution being applied to the trips.
- There is not a simple relationship between car park use and P&R bus boardings/alightings:
  - Some passengers boarding the P&R bus services do not park at the site (they are dropped off or walk);
  - Some people use the P&R car parks but then walk or cycle to their destination; and
  - Thornhill P&R is served by routes that are not defined as P&R in the OSM, such as the X90/Oxford Tube to London and the airport services.

In view of the issues noted with the ETM and survey data sources, the car park counts were considered to be the most reliable measure of overall P&R demand. The car park counts were therefore used to calculate target bus boardings and alightings at P&R sites. The calculation took into account the bus services which are defined as P&R services in the model and assumed a car occupancy of 1.1 for the AM and PM Peaks and 1.3 for the Inter Peak. The targets are presented in Table 5-12 and they were used as overall controls for the P&R matrices (see below).

Table 5-12 P&R Demand Targets

	Car Park Counts		ETM (All Routes)		ETM (P&R Routes)		Target Demand	
	Arrivals	Deps.	Boardings	Alightings	Boardings	Alightings	Boardings	Alightings
Peartree								
AM Peak	378	0	434	21	434	21	**415**	**21**
Inter Peak	265	197	417	171	417	171	**345**	**256**
PM Peak	27	374	78	219	78	219	**29**	**412**
All day	669	571	930	411	930	411	**736**	**649**
Redbridge								
AM Peak	514	12	515	19	469	8	**515**	**6**
Inter Peak	314	315	450	214	419	187	**380**	**359**
PM Peak	47	494	65	267	53	226	**42**	**461**
All day	874	822	1030	500	941	421	**878**	**771**
Water Eaton								
AM Peak	453	19	423	8	423	8	**499**	**21**
Inter Peak	241	253	306	177	306	177	**314**	**328**
PM Peak	25	453	20	193	20	193	**28**	**498**
All day	720	725	749	378	749	378	**792**	**797**
Seacourt								
AM Peak	434	9	278	7	278	7	**478**	**9**
Inter Peak	122	145	161	109	161	109	**158**	**188**
PM Peak	12	396	26	159	26	159	**14**	**436**
All day	568	550	466	275	466	275	**625**	**604**
Thornhill								
AM Peak	543	144	598	64	397	33	**397**	**82**
Inter Peak	402	404	420	265	237	143	**294**	**284**
PM Peak	177	531	129	547	56	204	**85**	**218**
All day	1122	1078	1147	875	690	380	**731**	**540**

5.4.4. Merging Data from Surveys and Ticket Records

As described above for bus-only trips, the ETM and survey matrices were merged using variance weighting. The data were disaggregated into separate matrices for each P&R site, and the variance weighting was carried out for each site separately. This enabled car leg matrices (between the trip production zone and P&R site) and bus leg matrices (between the P&R site and trip attraction zone) to be produced more readily at the end of the process.

The following steps were carried out to merge the survey and ETM matrices:

- combine ETM data for surveyed routes with the survey data using variance weighting techniques;
- adjust matrices so that the matrices for each P&R site only include trips to and from the defined catchment area for that site; and
- control total demand at each P&R site to the target demand based on car park entries and exits (see above).

Index of Dispersion

The variance and index of dispersion were calculated directly from the survey data, as described in section 5.3.1.

Due to the adjustments to the ETM data described above and the distribution of P&R fare stages over a broad catchment area, there was generally less confidence in the ETM matrices for P&R than for other bus services. Hence the index of dispersion was set at 50 for all cells in the matrix.

Assignment Matrices

The matrix building process described above generated full origin-destination P&R matrices for the AM Peak, Inter Peak and PM Peak periods. For assignment in the RTM and PTM, these matrices need to be converted into hourly car leg and bus leg matrices. This was readily achieved since the demand for each P&R site had been kept separate throughout the process.

The bus leg matrices were produced as follows:

- For trips towards Oxford, the leg of the journey from the P&R site to Oxford was extracted: the P&R demand for each site was aggregated across all origins to give a destination (row) vector – this vector formed the row in the bus leg matrix corresponding to the equivalent P&R site zone origin; and
- For trips returning from Oxford, the P&R demand for each site was aggregated across all destinations to give an origin (column) vector – this vector formed the column in the bus leg matrix corresponding to the equivalent P&R site zone destination.

The car leg matrices were produced similarly by extracting the car legs of the journey. Car leg matrices were divided by the car occupancy (1.1 for the AM and PM Peaks; 1.3 for the Inter Peak) to convert to vehicle trips.

Both car leg and bus leg matrices were converted to hourly flows using the peak period to peak hour factors, which were calculated from the car park arrivals data and which are presented in Table 5-13.

Table 5-13 P&R Peak Period to Peak Hour Factors

AM Factor	IP Factor	PM Factor
2.54	6	2.48

5.4.5. Matrix Characteristics

Table 5-14 shows the matrix totals for each stage in the matrix building process.

Table 5-14 P&R Matrix Totals

Matrix building stage	AM Peak Period	Inter Peak Period	PM Peak Period
Surveyed Matrix	2,228	4,211	2,196
ETM Matrix	1,976	2,231	1,175
Merged Matrix (Surveyed+ETM)	2,440	3,724	2,130
Factored Merged Matrix	2,443	2,459	2,223
	AM Peak Hour	**Inter Peak Average Hour**	**PM Peak Hour**
Hourly P&R Matrix	962	410	896

The average journey lengths for each matrix are shown in Table 5-15. This indicates that the ETM matrices and survey matrices are fairly similar in terms of average trip length, although the merging and factoring process tends to reduce the average trip length slightly.

Figure 5-10 to Figure 5-12 show the trip length distribution of the P&R demand matrices at each stage in the process. It can be seen that the distributions of the survey and ETM matrices differ even though the average trip lengths are similar.

Table 5-15 Average Journey Lengths

Matrix building stage	AM Peak Period	Inter Peak Period	PM Peak Period
Surveyed Matrix	39.69	43.10	43.88
ETM Matrix	41.53	42.61	40.86
Merged Matrix (Surveyed + ETM)	36.54	40.33	38.89
Factored Merged Matrix	37.87	38.55	37.16

Figure 5-10 AM Peak P&R Trip Length Distribution Comparison

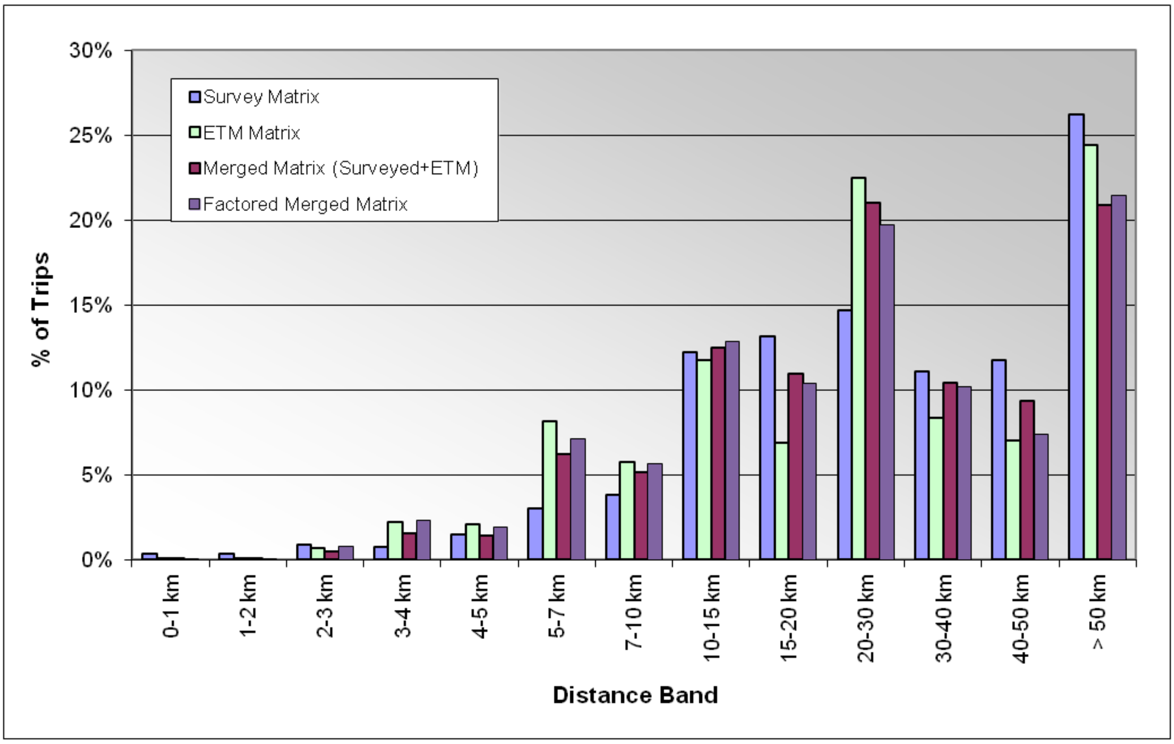


Figure 5-11 Inter Peak P&R Trip Length Distribution Comparison

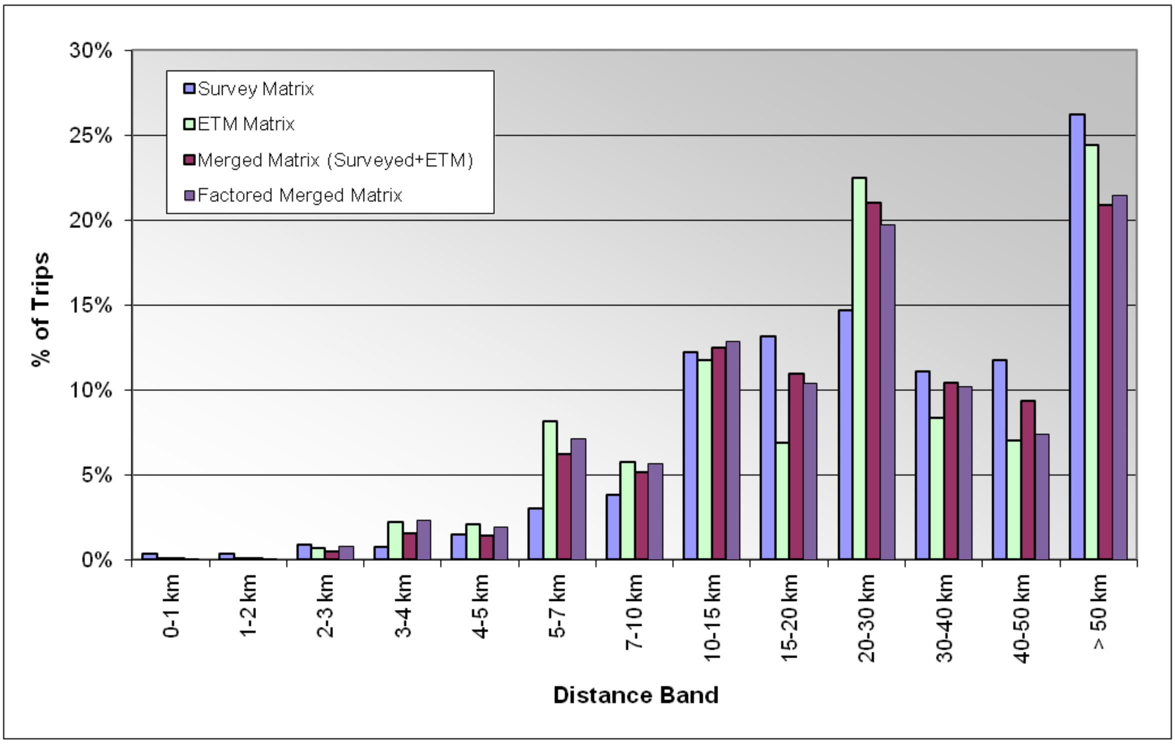
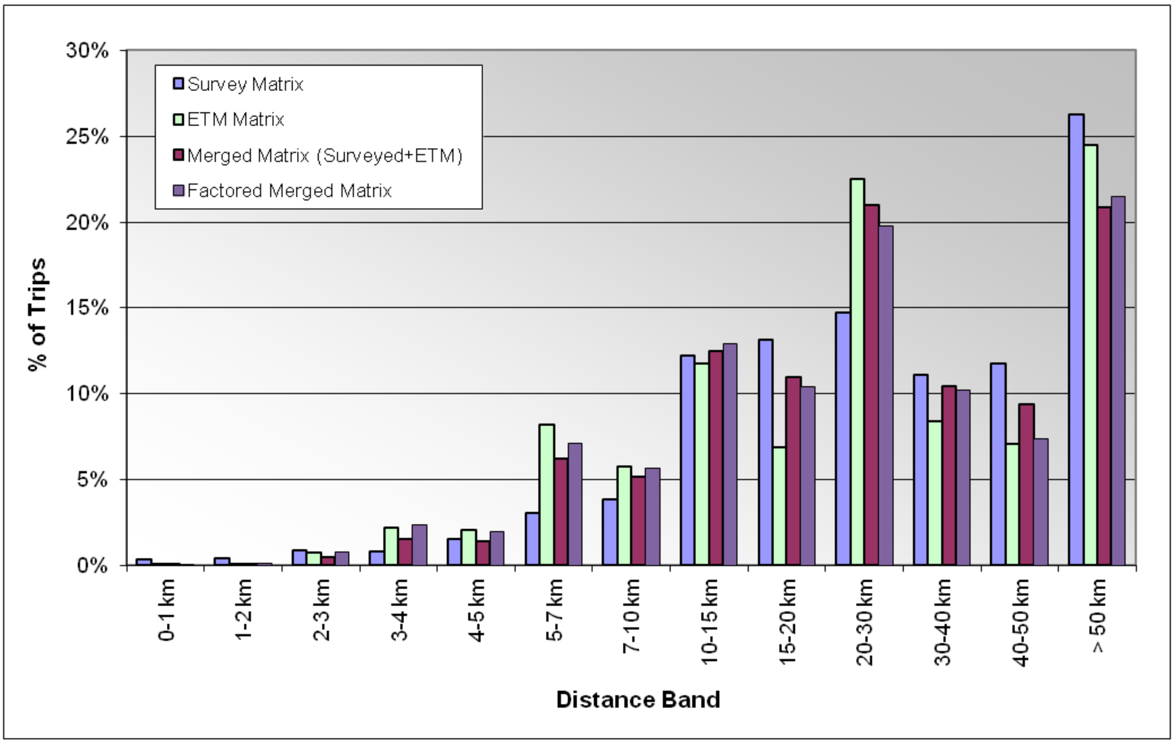


Figure 5-12 PM Peak P&R Trip Length Distribution Comparison



5.5. Rail Travel Demand Data

The following sources of rail demand data were available:

- Rail origin-destination surveys conducted on the platforms of Oxford, Didcot Parkway and Bicester stations in November 2013. Surveys were undertaken on the platforms[6] between 7am and 7pm on a single day;
- 'Bus-rail' trip records from bus origin-destination surveys conducted in November 2013;
- Annual ticketing data for 2013 taken from the First Great Western version of the MOIRA model, supplemented by data from the National MOIRA model for stations on the Chiltern Line; and
- Origin-destination data from the National Rail Traveller Survey, conducted in 2001 (and 2005 for some stations).

5.5.1. Rail Survey Data Processing

The 2013 rail surveys were conducted on the platforms at Oxford, Didcot Parkway and Bicester North stations. The survey questionnaire was similar to that used for the bus surveys (see Section 5.2.1 above).

In addition boarding and alighting counts were conducted for each rail service. These were used to calculate expansion factors.

The data were processed by:

- a series of checks to correct transcription errors and remove any inconsistent records;
- coding trip origins and destinations to OSM zones, using the coordinates of the origin and destination postcodes;
- allocating trips to model time periods;
- processing reverse direction trips; and
- calculating expansion factors.

[6] At Didcot Parkway, Platform 5 was not surveyed.

Reverse trips and expansion Factors

As the surveys were conducted on the station platforms, almost all of the respondents were interviewed when boarding the train, rather than on alighting from the train. However, the survey included a question on whether the rail journey was part of an identical return trip, and what time the other leg of the journey was made. These responses give information on passengers alighting at the three stations.

The non-interview direction trips were processed by interchanging the origin and destination and allocating them to the reverse trip time period and an appropriate rail platform for the reverse direction trip.

Expansion factors were calculated for each surveyed platform and time period, based on both the interview direction and reverse direction trips.

Adjustments were made to deal with double-counting of trips between Oxford and Didcot Parkway stations, which were included in both the Oxford and Didcot Parkway surveys. MOIRA data was analysed to determine the proportion of trips to Oxford that come from Didcot and the proportion of trips to Didcot that come from Oxford. The alightings at each station were reduced to remove the double-counted trips.

Table 5-16 shows the platform counts, number of passengers interviewed and overall expansion factors for each surveyed platform by time period[7]. Adjustments to passenger alightings to deal with double counting are shown in brackets.

Rail Survey Matrix Preparation

The survey contained questions about the mode of access to the railway station and the onwards mode to the final destination, as well as the bus service(s) used (if relevant). This allowed the survey records to be classified into:

- “bus-rail” trips that used one of the bus services covered by the bus origin-destination survey; and
- other rail trips.

[7] The time periods referred to here are AM Peak Period (0700-1000), Inter Peak Period (1000-1600) and PM Peak Period (1600-1900).

Table 5-16 Rail Platform Counts and Expansion Factors

Station	Platform	Time Period	Platform Counts		Passengers Interviewed		Total responses (Two Way)		Two-way Exp. Factor	
			Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
Bicester North	1	AM	160	129	23	1	23	16	6.96	8.06
Bicester North	1	IP	144	612	5	0	5	54	28.80	11.33
Bicester North	1	PM	198	536	1	1	1	37	198.00	14.49
Bicester North	2	AM	780	159	59	0	59	1	13.22	159.00
Bicester North	2	IP	493	380	54	0	55	2	8.96	190.00
Bicester North	2	PM	451	311	40	6	40	17	11.28	18.29
Didcot Parkway	1	AM	191	313	51	0	55	11	3.47	28.45
Didcot Parkway	1	IP	209	261	39	4	39	8	5.36	32.63
Didcot Parkway	1	PM	207	830	38	3	38	16	5.45	51.88
Didcot Parkway	2	AM	696	130 (73)	13	0	15	34	46.40	2.16
Didcot Parkway	2	IP	591	228 (142)	27	0	29	12	20.38	11.86
Didcot Parkway	2	PM	416	308 (183)	23	6	24	28	17.33	6.52
Didcot Parkway	3	AM	328	109	7	1	8	2	41.00	54.50
Didcot Parkway	3	IP	350	211	10	4	12	5	29.17	42.20
Didcot Parkway	3	PM	298	338	4	7	5	12	59.60	28.17
Didcot Parkway	4+5	AM	304	271 (153)	10	1	14	6	21.71	25.51
Didcot Parkway	4+5	IP	58	293 (183)	2	3	3	6	19.33	30.49
Didcot Parkway	4+5	PM	89	629 (373)	2	0	3	5	29.67	74.57
Oxford	1	AM	1368	1100	83	3	83	45	16.48	24.44
Oxford	1	IP	1460	604	90	6	91	25	16.04	24.16
Oxford	1	PM	1884	410	65	9	67	30	28.12	13.67
Oxford	2	AM	355	1513 (1184)	46	3	54	64	6.57	18.50
Oxford	2	IP	588	1861 (1589)	41	1	41	26	14.34	61.13
Oxford	2	PM	1394	1463 (1322)	47	4	50	58	27.88	22.80
Oxford	3	AM	18	205	1	0	1	6	18.00	34.17
Oxford	3	IP	193	153	0	0	0	0	n/a	n/a

Station	Platform	Time Period	Platform Counts		Passengers Interviewed		Total responses (Two Way)		Two-way Exp. Factor	
			Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
Oxford	3	PM	205	63	6	0	6	1	34.17	63.00
Total			13428	13420	787	63	821	527		

5.5.2. MOIRA Data Processing

MOIRA station-station matrices for the modelled periods on an average weekday were derived from annual MOIRA data by applying demand profiles. These matrices give demand to and from all stations in Oxfordshire, as well as trips to and from major stations in the surrounding area, such as Swindon and Reading. Through trips crossing the study area are not included.

Separate matrices were produced for surveyed (Oxford, Didcot Parkway and Bicester North) and non-surveyed stations.

5.5.3. Station to Zone Correspondence

A correspondence was produced to distribute the MOIRA station to station matrices to OSM zones. The correspondence was derived from NRTS data:

- Trip records to and from each station in the study area were extracted from the NRTS dataset. Each record included the origin and destination postcode sectors, allowing a station to postcode sector correspondence to be derived.
- GIS was used to identify the OSM zones associated with each postcode sector.
- Factors were derived to disaggregate from postcode sectors to zones, based on:
  - the distance of the zone centroid from the station; and
  - zonal population from the 2011 census (the maximum of the "daytime population" and the “resident population” was used in order to take account of zones containing employment but only limited amounts of housing).

For larger external zones, the demand was simply allocated to the zone containing the station.

5.6. Rail Matrices

5.6.1. Merging Data from Surveys and MOIRA

As described above for bus-only trips, the MOIRA[8] and survey matrices were merged using variance weighting. The process included the following steps:

- combine survey data for “bus-rail” trips from the bus and rail surveys using variance weighting;
- add in the rest of the surveyed trips, and control the combined survey matrix totals for each time period to the original rail survey matrix totals by time period;
- combine the MOIRA data for surveyed stations with the merged survey data matrices using variance weighting techniques;
- adjust matrices so that the total 12-hour demand is controlled to the MOIRA total, but retain the survey distribution of trips on a broad sector basis[9]; and
- add in the MOIRA demand for non-surveyed stations.

Index of Dispersion

The variance and index of dispersion were calculated directly from the survey data, as described in section 5.3.1.

The index of dispersion for the merged survey matrix was taken as the minimum of the indices for the three constituent matrices.

[8] It is noted here that through trips (passing through the County by rail) were not extracted from MOIRA or included in the matrix development. This will have no consequence on routing or assignment as public transport crowding is not allowed for in the model. However, this will have an impact if train loadings are to be examined or the wider impacts of service enhancements on through movements and business case is looked into.

[9] In addition, trips to and from Milton Park were controlled to survey data totals in order to retain the information on trips using the M10 bus service.

For the MOIRA matrices, the index of dispersion was set at 20 for all cells.

The rail demand matrices were converted to hourly demand using the peak period to peak hour factors, which were calculated from survey data for Oxford, Bicester and Didcot Parkway and from MOIRA for other stations. The factors are presented in Table 5-17.

Table 5-17 Rail Peak Period to Peak Hour Factors

Station	AM Boardings	AM Alightings	IP	PM Boardings	PM Alightings
Bicester North	4.1	2.7	6.0	3.9	3.6
Didcot Parkway	2.2	2.3	6.0	2.1	2.2
Oxford	2.5	1.8	6.0	2.3	2.7
Other Stations	2.86	2.86	6.0	2.28	2.28

5.6.2. Matrix Characteristics

Table 5-18 shows the matrix totals for each stage in the matrix building process.

Table 5-18 Rail Matrix Totals

Matrix building stage	AM Peak Period	Inter Peak Period	PM Peak Period
Merged Survey Matrix	7,624	8,221	9,506
MOIRA Matrix (Surveyed Stations)	7,113	7,388	7,735
Merged Matrix (Surveyed+MOIRA)	6,703	7,179	8,353
Merged Matrix Including Unsurveyed Stations	9,302	9,824	11,112
	AM Peak Hour	**Inter Peak Average Hour**	**PM Peak Hour**
Hourly Rail Matrix	3,955	1,637	4,477

Figure 5-13 to Figure 5-15 show the trip length distribution of the rail demand matrix at each stage in the process. It can be seen that the MOIRA matrices for surveyed stations contain a higher proportion of trips in the distance range 100-150 km, but this difference is smoothed out when the matrices are merged.

The average journey lengths for each matrix are shown in Table 5-19. This indicates that the MOIRA matrices for surveyed stations have a shorter average trip length than the survey matrices. In the Inter Peak the survey matrix contains a number of long trips (> 200 km) that increase the average trip length.

Table 5-19 Average Journey Lengths

Matrix building stage	AM Peak Period	Inter Peak Period	PM Peak Period
Merged Survey Matrix	99.13	112.32	98.83
MOIRA Matrix (Surveyed Stations)	92.47	87.25	90.99
Merged Matrix (Surveyed+MOIRA)	91.18	102.15	90.80
Merged Matrix Including Unsurveyed Stations	97.14	103.86	95.89

Figure 5-13 AM Peak Rail Trip Length Distribution Comparison

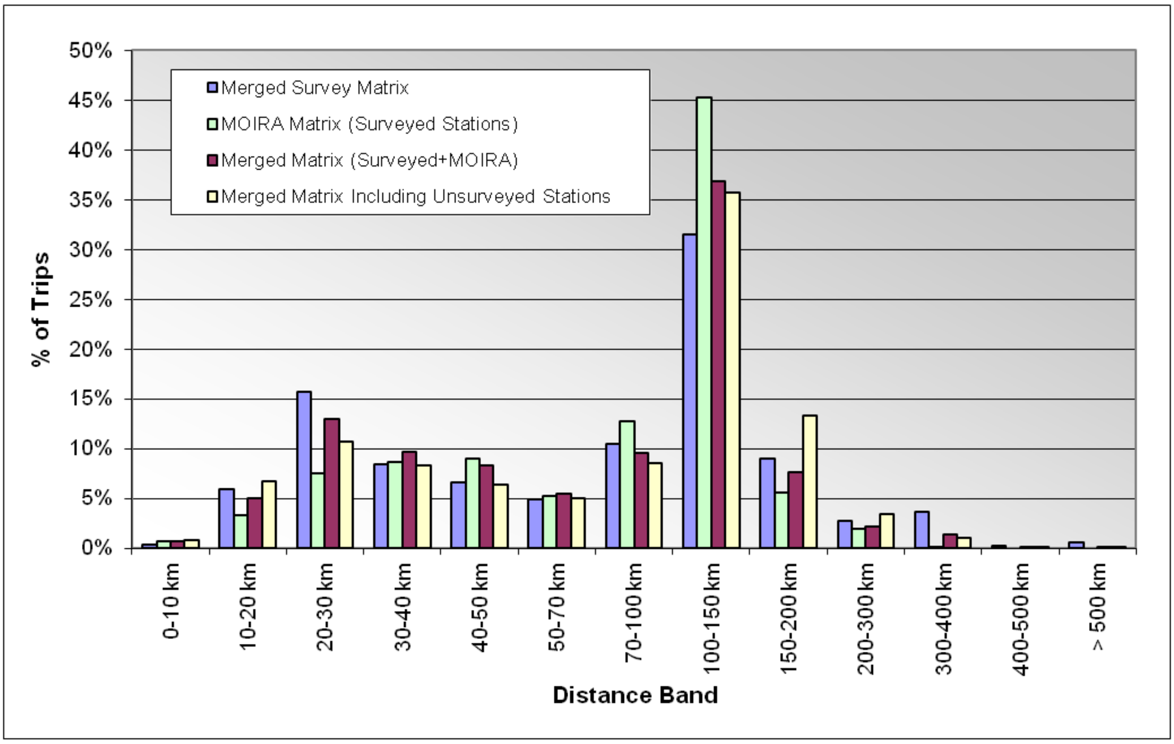


Figure 5-14 Inter Peak Rail Trip Length Distribution Comparison

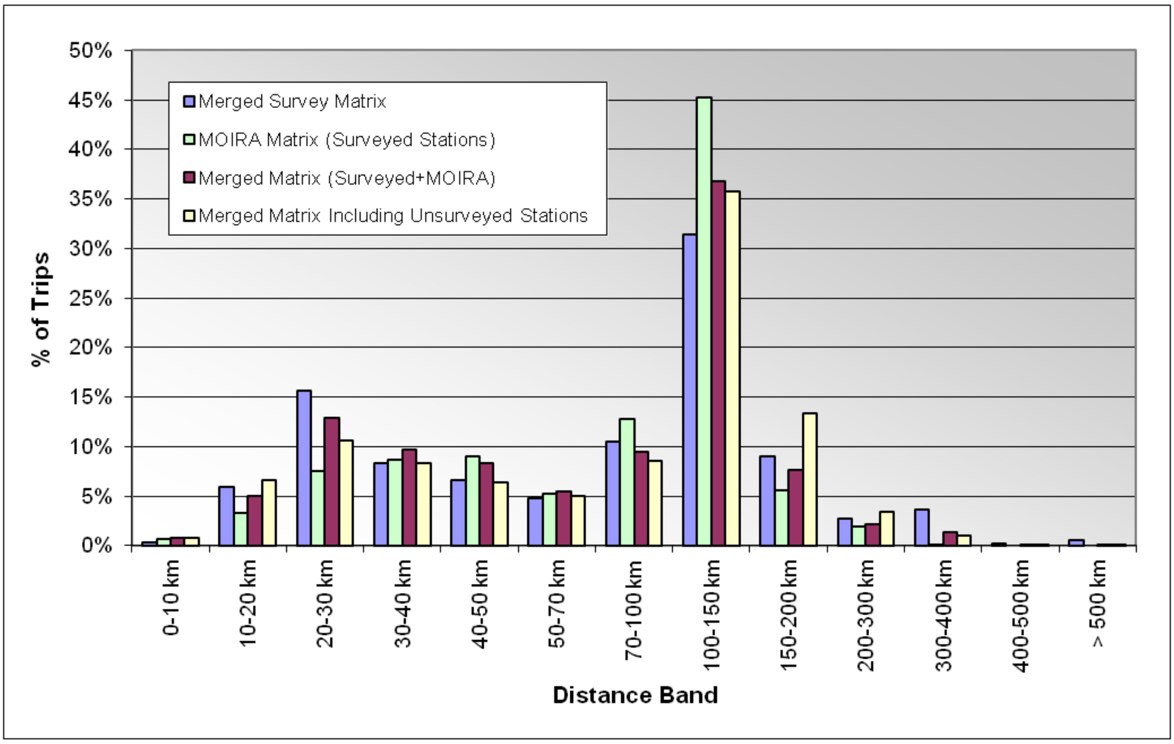
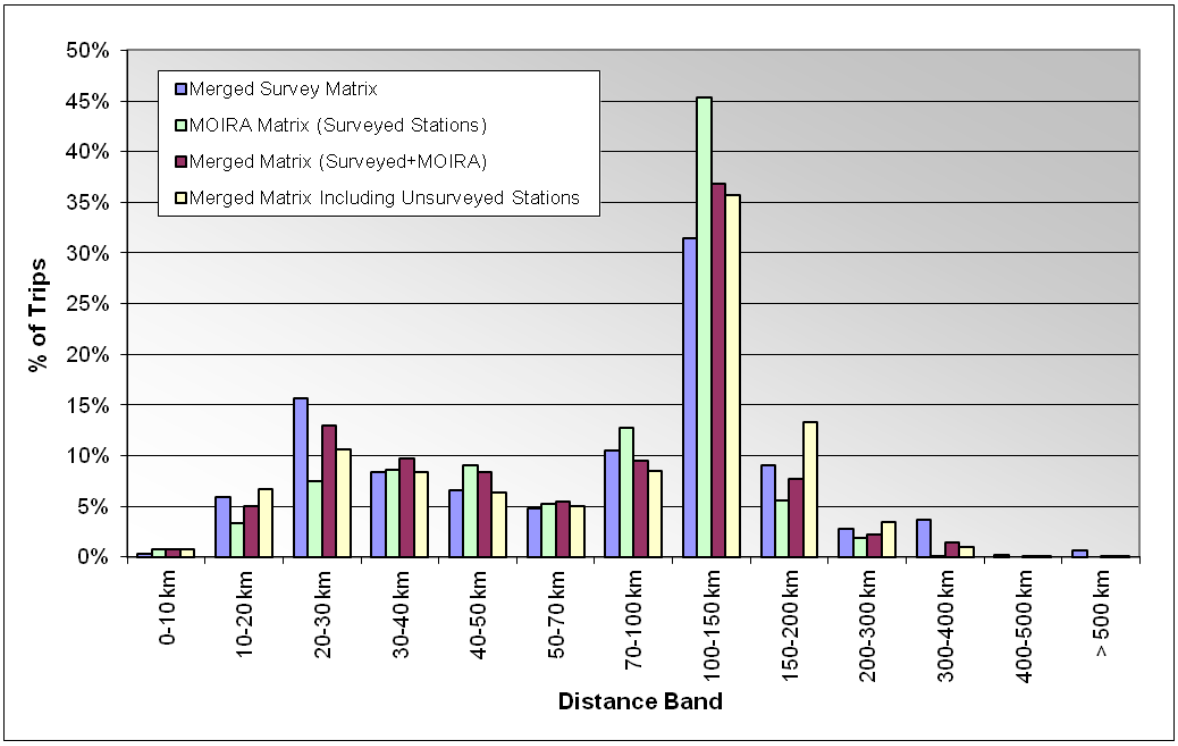


Figure 5-15 PM Peak Rail Trip Length Distribution Comparison



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6. Assignment Results

6.1. Bus Assignment

Some key statistics from the bus assignment are presented below.

Table 6-1 Summary Bus Assignment Statistics

	AM Peak	Inter Peak	PM Peak
Average Wait Time (minutes)	4.1	3.9	3.8
Average Walk Time (minutes)	16.1	17.1	17.0
Average Boardings Per Passenger	1.1	1.1	1.1

Having relied on ETM demand data, we might expect the modelled number of bus transfers to be too low, because a journey with an interchange will appear as two separate trips in the ETM matrix. However, analysis of the survey data indicates that about 11% of bus trips involve a transfer, so average boardings per passenger of 1.1 seem reasonable.

Figure 6-1 shows the main bus interchange points in the AM Peak (only nodes with at least 5 interchange boardings are displayed). The locations with the highest volumes of interchanges are:

- bus stops in Oxford city centre;
- St. Clements;
- the junction between Banbury Road and Marston Ferry Road (where a number of north/south services intersect with east/west routes serving Headington and the John Radcliffe hospital);
- the junction of London Road and Windmill Road; and
- Abingdon town centre (not shown in **Figure 6-1**).

The main interchange points are similar in the Inter Peak and PM Peak.

Figure 6-1 AM Peak Main Bus Interchange Points

6.2. Rail Assignment

Some key statistics from the bus assignment are presented below. For the rail assignment, “average walk time” is not presented because many rail passengers make long journeys by car to access the station, so this measure is not very informative.

Table 6-2 Summary Rail Assignment Statistics

	AM Peak	Inter Peak	PM Peak
Average Wait Time (minutes)	8.0	8.7	9.4
Average Boardings Per Passenger	1.3	1.3	1.3

6.3. Public Transport Flows

Figure 6-2 to Figure 6-4 show bus and rail flows on the public transport network in each time period.

Note that the rail demand only includes trips to and from Oxfordshire, and does not include through demand. Consequently there are only light flows on the section of the Great Western Main Line between Swindon and Didcot.

Figure 6-2 AM Peak Public Transport Flows

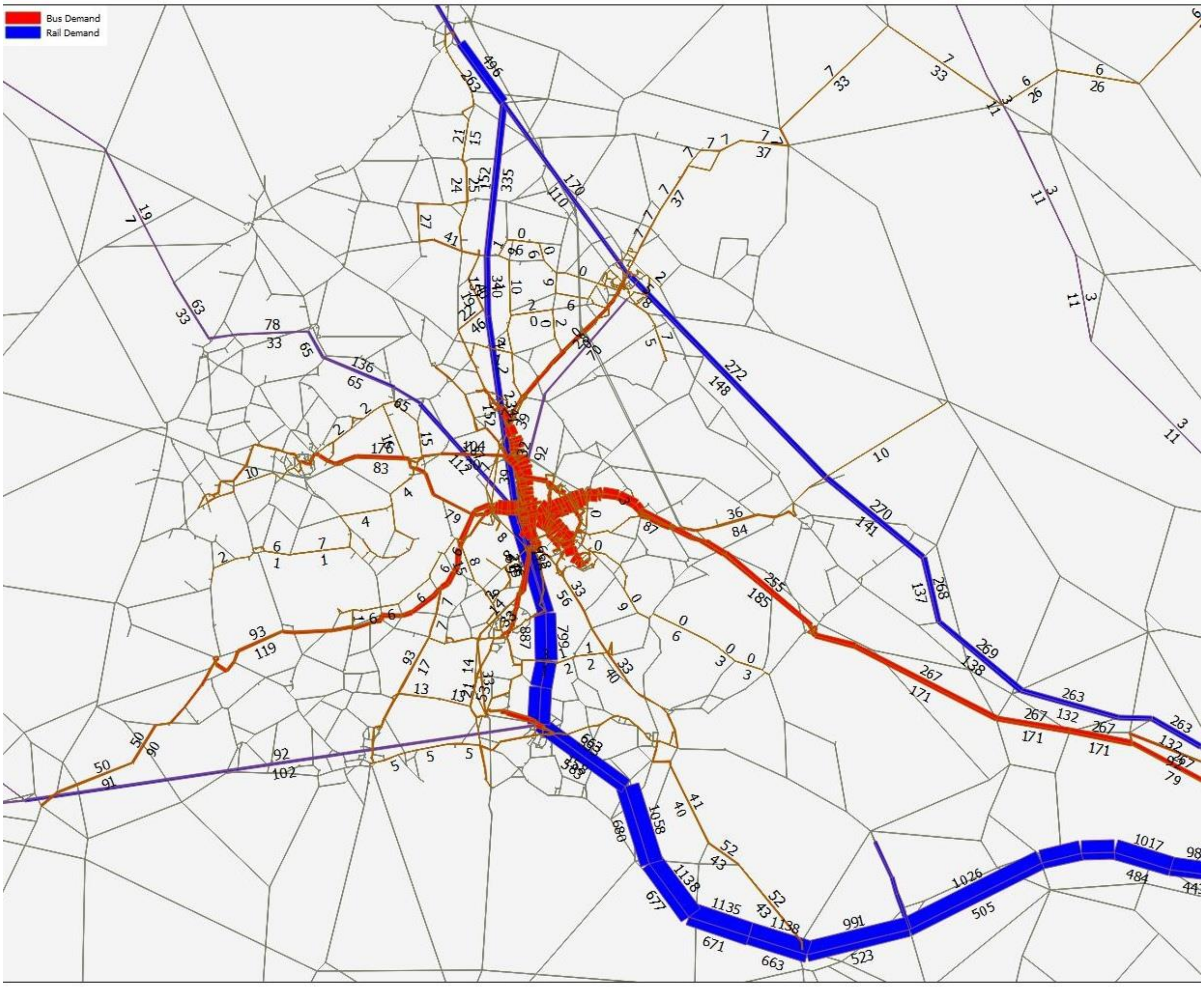


Figure 6-3 Inter Peak Public Transport Flows

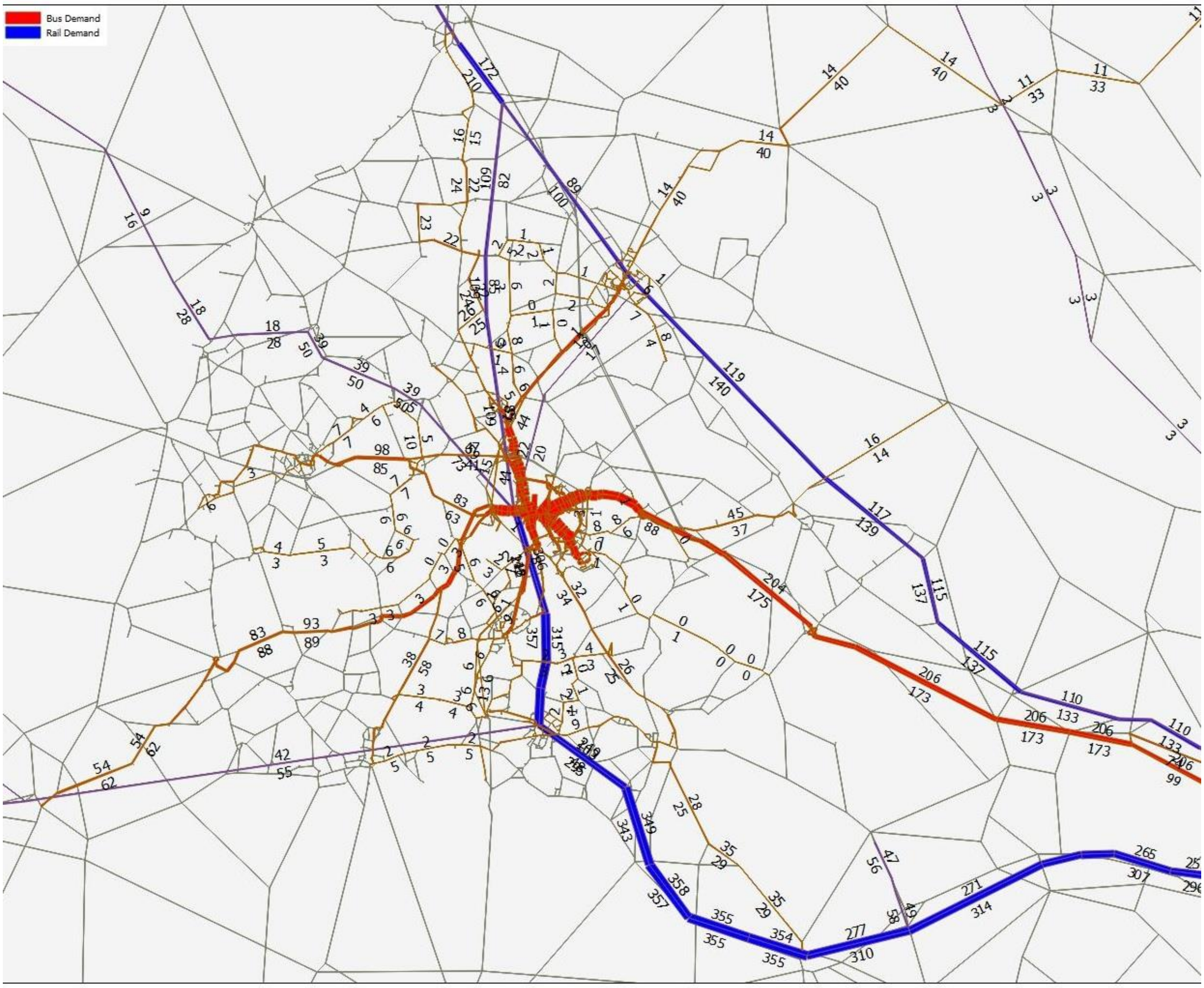
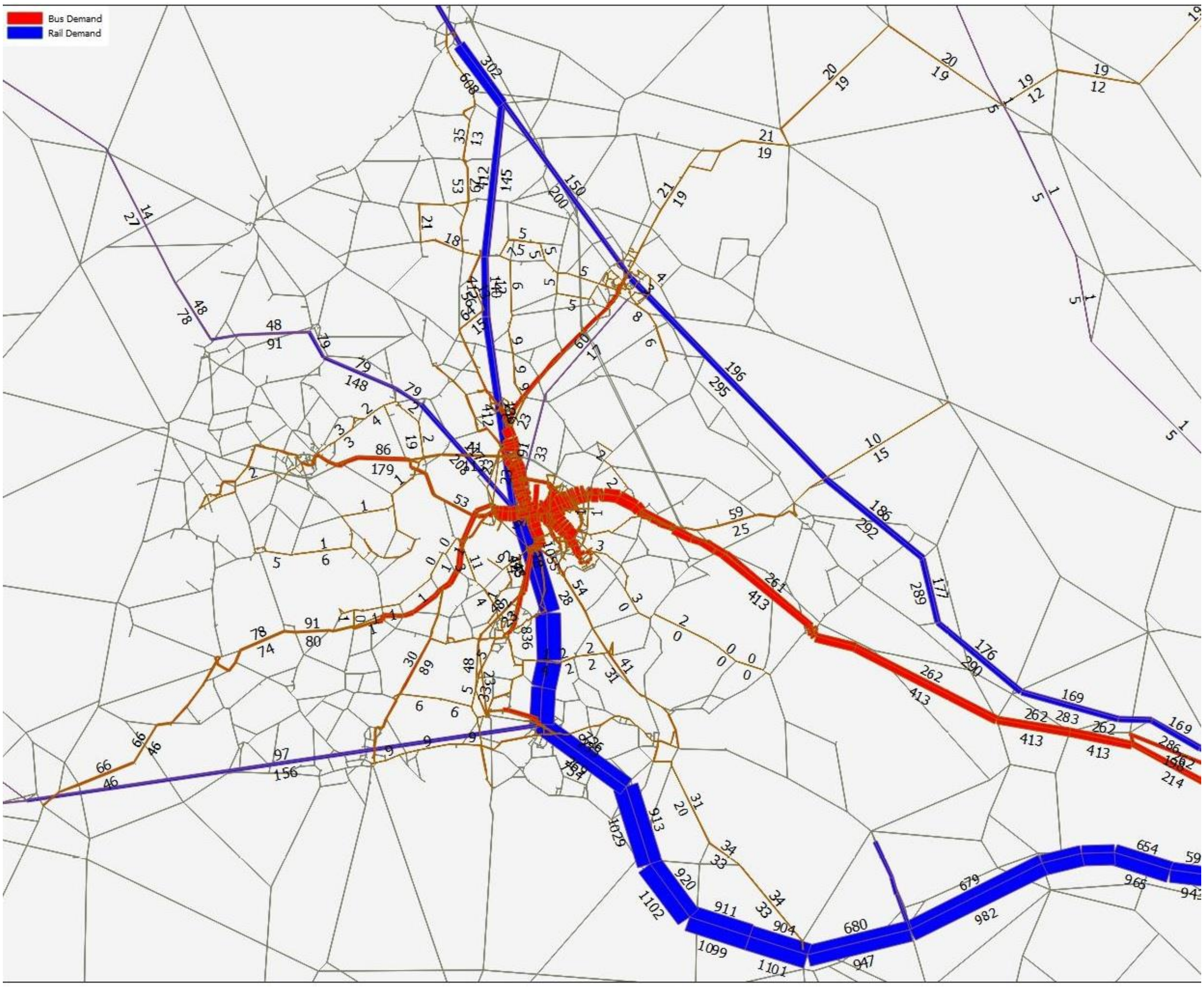


Figure 6-4 PM Peak Public Transport Flows



7. Calibration and Validation

7.1. Calibration and Validation Data

7.1.1. Bus Data

The following sources of observed bus data were available for the calibration and validation of the PTM:

1. Boarding and alighting counts collected in conjunction with bus origin-destination surveys in November 2013. Counts were undertaken on-board, rather than from the roadside, ensuring a higher level of accuracy. Each route was surveyed on one or two days. Summaries of the bus sample rates obtained in each time period are given in Table 5-2 to Table 5-4 in Chapter 5, and further details of the survey can be found in the Data Collection Report.
2. Calculations of the number of passengers on the bus at specific points along the route, derived from Electronic Ticket Machine (ETM) data. This is an average over a four-week period.
3. Counts of boardings and alightings at bus stops, carried out in 2007-8. Each stop was surveyed on a single day. This source was not used due to its age and changes to bus routes between 2007-8 and 2013.
4. Bus and rail journey times from timetables.

Either ETM data or boarding and alighting count data or both were collected for the vast majority of bus routes in the model. See Table 5-1 in Chapter 5 for a summary of the data available for each route. Where the ETM data source was available, this was used in preference to count data as it takes account of average demand across a four-week period, rather than being based on a sample of buses on one or two days. There are quite significant fluctuations in demand on many bus routes throughout the day, as well as day-to-day variation, so the count data is subject to greater uncertainty, particularly for routes for which a lower sample rate was achieved.

It should be noted that neither the ETM data nor the boarding and alighting counts are truly independent sources, since both were used in the matrix building process. Independent validation of the bus demand matrix was therefore not possible, although a careful calibration was undertaken.

The trip matrix calibration focused on comparing total modelled and observed flows of passengers across three cordons around Oxford, Bicester and Didcot, as shown in Figure 7-1 - Figure 7-3.

A more detailed analysis of link flows across the cordons formed the basis for the bus assignment validation. This indicates whether the demand has been appropriately assigned to bus routes in the model.

Figure 7-1 Location of Oxford Cordon

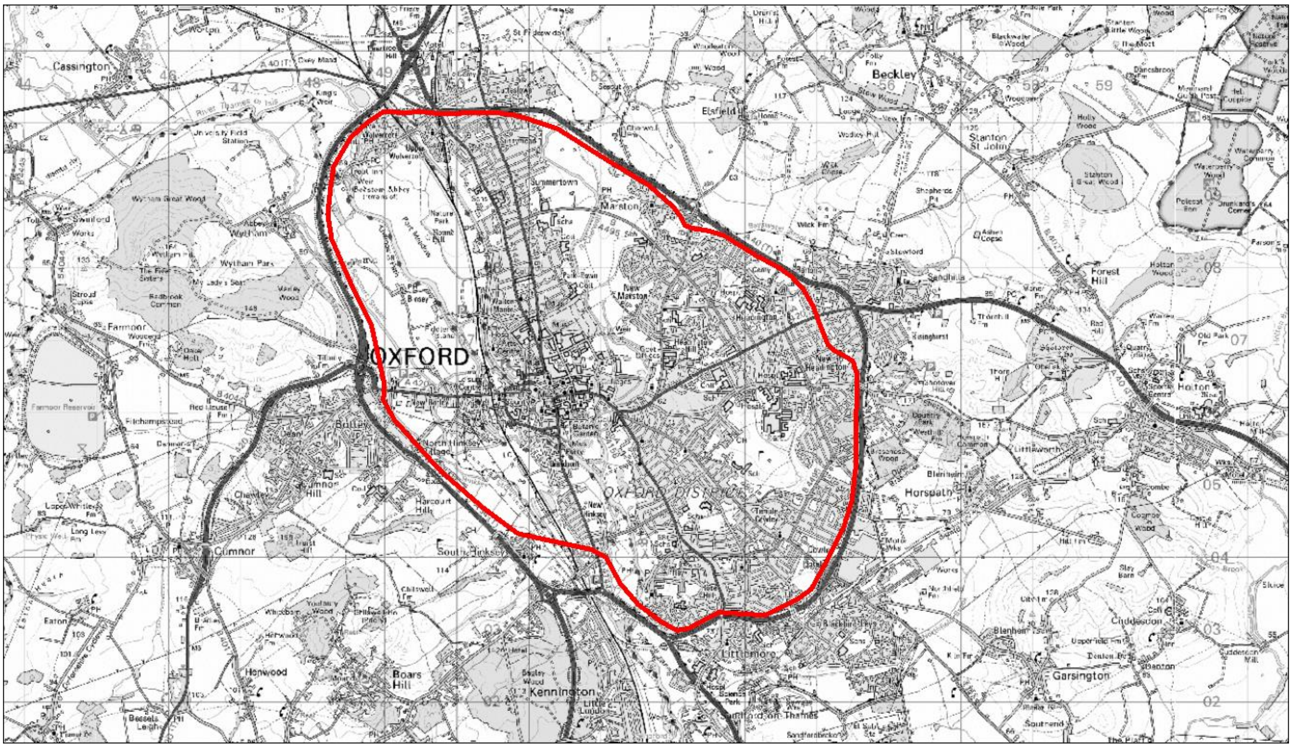


Figure 7-2 Location of Bicester Cordon

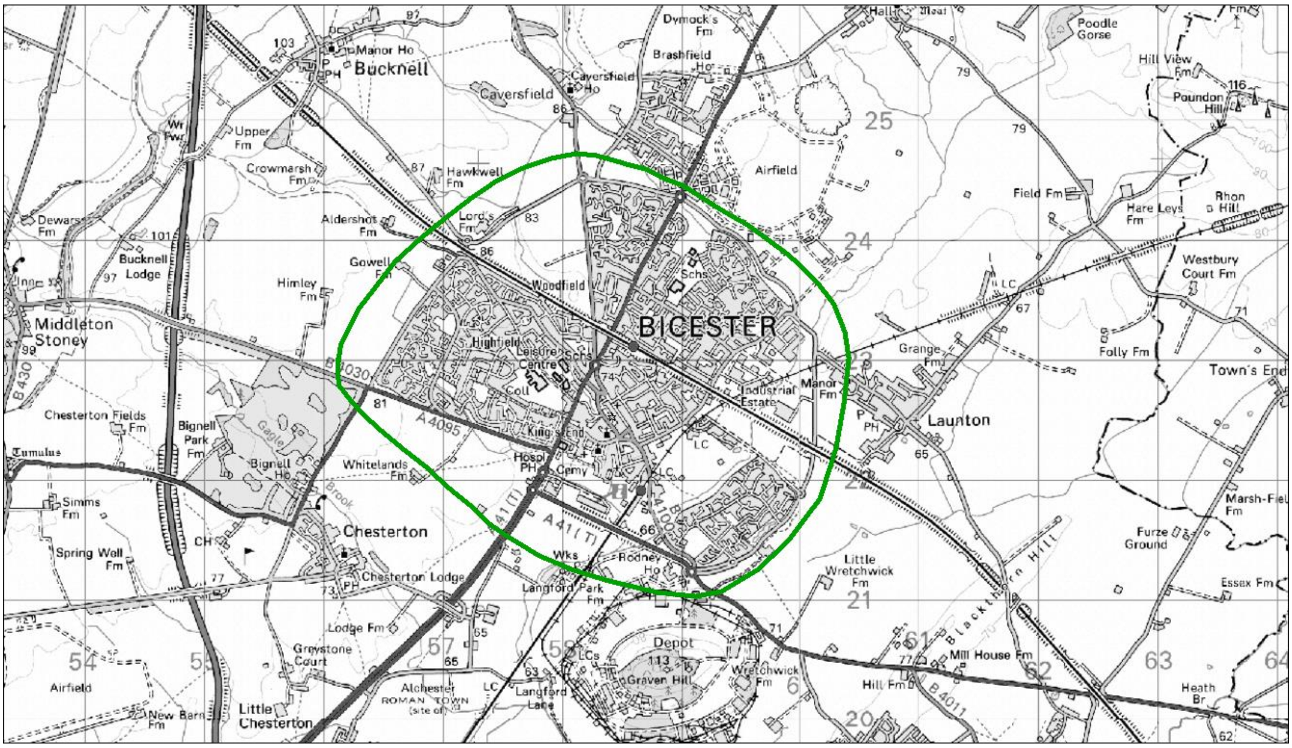


Figure 7-3 Location of Didcot Cordon

7.1.2. Rail Data

The following sources of observed rail data were available for the calibration and validation of the PTM:

1. Boarding and alighting counts at Oxford, Didcot Parkway and Bicester stations, collected in conjunction with rail origin-destination surveys in November 2013. Counts were undertaken on the platforms[10] for all services arriving and departing between 7am and 7pm on a single day. As passengers were observed on the platforms, the counts include interchanging passengers.
2. All-day estimates of boardings and alightings for an average weekday, derived from annual MOIRA ticketing data for 2013. MOIRA only considers the initial and final stations on the journey, so the estimates do not include interchanging passengers.
3. Counts from the National Rail Traveller Survey, conducted in 2001 (and 2005 for some stations). This source was considered to be too old for the purposes of validation and was not used.
4. Annual station usage data, derived from ticket sales data.

Rail trip matrix validation was not possible as counts of passengers crossing screenlines and cordons were not available. Assignment validation consisted of comparing modelled boardings and alightings with the observed data.

7.2. Bus Matrix Calibration

As described above, the data available did not allow for a truly independent bus matrix validation, but data used in the matrix building process could be drawn on for a calibration. The bus matrix calibration involved the comparison of observed and modelled flows across three cordons (Figure 7-1 to **Figure 7-3**). Overall, the criterion of modelled flows being within 15% of observed flows was met for 17 out of 18 cordon crossings (by direction and time period). The results for each cordon are given below in Table 7-1.

[10] At Didcot Parkway, Platform 5 was not surveyed.

In the PM Peak the modelled flow outbound across the Didcot cordon was not within 15% of the observed flow. However, at only 83 passengers, the observed flow across the cordon is very small, and the difference between the modelled and observed flow is not great in absolute terms.

Table 7-1 Bus Matrix Calibration

Cordon and time period	Observed (Passengers)	Modelled (Passengers)	% Difference	Passed?
AM Peak				
Oxford Cordon Inbound	4186	3798	-9%	Yes
Oxford Cordon Outbound	1809	1810	-0%	Yes
Bicester Cordon Inbound	140	154	10%	Yes
Bicester Cordon Outbound	180	183	2%	Yes
Didcot Cordon Inbound	128	168	31%	No
Didcot Cordon Outbound	411	371	-10%	Yes
Inter Peak				
Oxford Cordon Inbound	2013	1857	-8%	Yes
Oxford Cordon Outbound	1965	1884	-4%	Yes
Bicester Cordon Inbound	163	175	7%	Yes
Bicester Cordon Outbound	130	136	5%	Yes
Didcot Cordon Inbound	60	56	-7%	Yes
Didcot Cordon Outbound	61	60	-2%	Yes
PM Peak				
Oxford Cordon Inbound	1857	1827	-2%	Yes
Oxford Cordon Outbound	3953	3536	-11%	Yes
Bicester Cordon Inbound	222	246	11%	Yes
Bicester Cordon Outbound	135	141	4%	Yes
Didcot Cordon Inbound	338	340	1%	Yes
Didcot Cordon Outbound	83	124	49%	No

7.3. Network and Service Validation

The PTM bus network is identical in structure to the validated highway network. Checks on the accuracy of the coded network geometry are covered in the RTM Development Report. The rail network is very simple and only consists of a limited number of links. Checks were made on the coded station to station distances. Checks were also made to ensure that modelled bus routes cross the validation cordons at the correct locations.

Bus journey times are linked to times on the highway network. Table 7-2 to Table 7-4 below give a comparison of modelled bus journey times against timetabled times for a selection of routes. In each of the time periods, a high proportion of the modelled journey times are within 15% of the timetabled times:

- AM Peak: 94% of routes within 15%
- Inter Peak: 97% of routes within 15%
- PM Peak: 93% of routes within 15%

Table 7-2 Bus Journey Time Comparison – AM Peak

Transit line	Description	Timetable	Modelled JT	% Difference	Passed?
10I	John Radcliffe - Oxford	55	51	-8%	Yes
10O	Oxford - John Radcliffe	50	47	-6%	Yes
12I	Greater Leys - Oxford	36	36	0%	Yes
12O	Oxford - Greater Leys	22	24	9%	Yes
18I	Bampton - Oxford	80	81	1%	Yes
18O	Oxford - Bampton	37	42	14%	Yes
1I	Blackbird Leys - Oxford	32	34	6%	Yes
1O	Oxford - Blackbird Leys	30	32	6%	Yes
23BisC	Bicester - Caversfield	45	44	-2%	Yes
25AI	Bicester - Oxford	69	70	1%	Yes
25AO	Oxford - Bicester	52	59	13%	Yes
280I	Oxford - Aylesbury	85	92	8%	Yes
280O	Aylesbury - Oxford	96	96	0%	Yes
2OX_I	Kidlington - Oxford	54	45	-16%	No
2OX_O	Oxford - Kidlington	39	40	2%	Yes
2SX_I	Kidlington - Oxford	52	45	-13%	Yes
2SX_O	Oxford - Kidlington	21	24	12%	Yes
35I	Abingdon - Oxford	54	47	-13%	Yes
35O	Oxford - Abingdon	33	32	-4%	Yes
3I	Rose Hill - Oxford	29	28	-3%	Yes
3O	Oxford - Rose Hill	24	23	-4%	Yes
5I	Blackbird Leys - Oxford	37	38	4%	Yes
5O	Oxford - Blackbird Leys	36	33	-10%	Yes
66I	Southmoor - Oxford	25	28	10%	Yes
66O	Oxford - Southmoor	25	27	9%	Yes
6I	LowerWolvercote - Oxford	16	16	-1%	Yes
6O	Oxford - Lower Wolvercote	15	14	-5%	Yes
8I	Barton - Oxford	44	40	-9%	Yes
8O	Oxford - Barton	28	31	11%	Yes
98C	Didcot - Orchard Centre	17	17	0%	Yes
M10C	Milton Park - Didcot Parkway	25	24	-3%	Yes
P300I	Peartree - Redbridge	27	30	12%	Yes
P300O	Redbridge - Peartree	27	27	-2%	Yes
P400I	Thornhill - Seacourt	36	41	13%	Yes
P400O	Seacourt - Thornhill	35	40	13%	Yes
P500I	Water Eaton - Oxford	14	19	36%	No
P500O	Oxford - Water Eaton	15	16	7%	Yes
P700I	Kidlington - Headington	49	46	-6%	Yes
P700O	Headington - Kidlington	51	45	-11%	Yes
P800I	Thornhill - John Radcliffe	15	14	-7%	Yes
P800O	John Radcliffe - Thornhill	19	16	-14%	Yes
P900I	Thornhill - Headington	13	14	11%	Yes

Transit line	Description	Timetable	Modelled JT	% Difference	Passed?
P900O	Headington - Thornhill	14	16	12%	Yes
S1I	Carterton - Oxford	92	80	-13%	Yes
S1O	Oxford - Carterton	60	54	-10%	Yes
S2I	Brize Norton - Oxford	68	78	15%	Yes
S2O	Oxford - Brize Norton	43	54	25%	No
S3I	Chipping Norton - Oxford	74	64	-13%	Yes
S3O	Oxford - Chipping Norton	59	51	-13%	Yes
S4I	Banbury - Oxford	86	94	9%	Yes
S4O	Oxford - Banbury	85	86	1%	Yes
S5AI	St George - Oxford	67	67	1%	Yes
S5AO	Oxford - St George	56	56	1%	Yes
T1I	Watlington - Oxford	53	56	6%	Yes
T1O	Oxford - Watlington	57	58	2%	Yes
U1I	Harcourt Hill - Wheatley	62	57	-9%	Yes
U1O	Wheatley - Harcourt Hill	62	57	-8%	Yes
vilI	Bicester Village Shuttle	7	6	-14%	Yes
vilO	Bicester Village Shuttle	7	6	-12%	Yes
X13I	Abingdon - John Radcliffe	53	43	-19%	No
X13O	John Radcliffe - Abingdon	49	43	-13%	Yes
X2I	Wallingford - Oxford	79	80	1%	Yes
X2O	Oxford - Wallingford	75	75	0%	Yes
X30I	Wantage - Oxford	53	56	5%	Yes
X30O	Oxford - Wantage	44	48	9%	Yes
X39I	Wallingford - Oxford	43	44	3%	Yes
X39O	Oxford - Wallingford	35	36	2%	Yes
X3I	Abingdon - Oxford	31	34	9%	Yes
X3O	Oxford - Abingdon	24	24	-1%	Yes

Table 7-3 Bus Journey Time Comparison – Inter Peak

Transit line	Description	Timetable	Modelled JT	% Difference	Passed?
10I	John Radcliffe - Oxford	52	47	-11%	Yes
10O	Oxford - John Radcliffe	52	46	-11%	Yes
12I	Greater Leys - Oxford	36	35	-4%	Yes
12O	Oxford - Greater Leys	24	26	10%	Yes
18I	Bampton - Oxford	57	62	9%	Yes
18O	Oxford - Bampton	57	60	5%	Yes
1I	Blackbird Leys - Oxford	31	33	5%	Yes
1O	Oxford - Blackbird Leys	30	32	7%	Yes
23BisC	Bicester - Caversfield	45	44	-2%	Yes
25AI	Bicester - Oxford	51	54	5%	Yes
25AO	Oxford - Bicester	52	58	11%	Yes
280I	Oxford - Aylesbury	82	83	1%	Yes

Transit line	Description	Timetable	Modelled JT	% Difference	Passed?
280O	Aylesbury - Oxford	84	86	2%	Yes
2OX_I	Kidlington - Oxford	42	36	-14%	Yes
2OX_O	Oxford - Kidlington	37	36	-3%	Yes
2SX_I	Kidlington - Oxford	42	36	-14%	Yes
2SX_O	Oxford - Kidlington	21	22	7%	Yes
35I	Abingdon - Oxford	41	37	-9%	Yes
35O	Oxford - Abingdon	28	27	-5%	Yes
3I	Rose Hill - Oxford	26	25	-4%	Yes
3O	Oxford - Rose Hill	27	24	-11%	Yes
5I	Blackbird Leys - Oxford	37	36	-3%	Yes
5O	Oxford - Blackbird Leys	38	33	-13%	Yes
66I	Southmoor - Oxford	25	26	5%	Yes
66O	Oxford - Southmoor	25	27	7%	Yes
6I	LowerWolvercote - Oxford	16	15	-6%	Yes
6O	Oxford - Lower Wolvercote	15	14	-4%	Yes
8I	Barton - Oxford	36	32	-10%	Yes
8O	Oxford - Barton	26	28	9%	Yes
98C	Didcot - Orchard Centre	15	15	1%	Yes
M10C	Milton Park - Didcot Parkway	30	31	2%	Yes
P300I	Peartree - Redbridge	23	30	32%	No
P300O	Redbridge - Peartree	23	25	10%	Yes
P400I	Thornhill - Seacourt	31	35	11%	Yes
P400O	Seacourt - Thornhill	31	36	15%	Yes
P500I	Water Eaton - Oxford	14	15	4%	Yes
P500O	Oxford - Water Eaton	15	15	-1%	Yes
P700I	Kidlington - Headington	44	42	-5%	Yes
P700O	Headington - Kidlington	49	45	-9%	Yes
P800I	Thornhill - John Radcliffe	12	13	5%	Yes
P800O	John Radcliffe - Thornhill	15	13	-12%	Yes
P900I	Thornhill - Headington	13	13	-1%	Yes
P900O	Headington - Thornhill	13	14	7%	Yes
S1I	Carterton - Oxford	62	56	-9%	Yes
S1O	Oxford - Carterton	57	53	-7%	Yes
S2I	Brize Norton - Oxford	70	73	4%	Yes
S2O	Oxford - Brize Norton	45	51	12%	Yes
S3I	Chipping Norton - Oxford	71	61	-13%	Yes
S3O	Oxford - Chipping Norton	59	51	-14%	Yes
S4I	Banbury - Oxford	81	85	4%	Yes
S4O	Oxford - Banbury	82	83	2%	Yes
S5AI	St George - Oxford	63	59	-6%	Yes
S5AO	Oxford - St George	55	56	2%	Yes
T1I	Watlington - Oxford	55	56	2%	Yes
T1O	Oxford - Watlington	57	58	1%	Yes

Transit line	Description	Timetable	Modelled JT	% Difference	Passed?
U1I	Harcourt Hill - Wheatley	57	50	-12%	Yes
U1O	Wheatley - Harcourt Hill	57	49	-14%	Yes
vilI	Bicester Village Shuttle	7	6	-13%	Yes
vilO	Bicester Village Shuttle	7	6	-15%	Yes
X13I	Abingdon - John Radcliffe	48	38	-22%	No
X13O	John Radcliffe - Abingdon	45	38	-15%	Yes
X2I	Wallingford - Oxford	77	75	-3%	Yes
X2O	Oxford - Wallingford	79	74	-7%	Yes
X30I	Wantage - Oxford	43	47	8%	Yes
X30O	Oxford - Wantage	44	46	5%	Yes
X39I	Wallingford - Oxford	43	43	0%	Yes
X39O	Oxford - Wallingford	35	34	-3%	Yes
X3I	Abingdon - Oxford	23	26	11%	Yes
X3O	Oxford - Abingdon	22	20	-8%	Yes

Table 7-4 Bus Journey Time Comparison – PM Peak

Transit line	Description	Timetable	Modelled JT	% Difference	Passed?
10I	John Radcliffe - Oxford	54	50	-8%	Yes
10O	Oxford - John Radcliffe	52	49	-6%	Yes
12I	Greater Leys - Oxford	37	35	-4%	Yes
12O	Oxford - Greater Leys	25	28	13%	Yes
18I	Bampton - Oxford	54	54	0%	Yes
18O	Oxford - Bampton	67	70	4%	Yes
1I	Blackbird Leys - Oxford	31	32	4%	Yes
1O	Oxford - Blackbird Leys	30	34	12%	Yes
23BisC	Bicester - Caversfield	45	44	-2%	Yes
25AI	Bicester - Oxford	47	53	13%	Yes
25AO	Oxford - Bicester	62	68	9%	Yes
280I	Oxford - Aylesbury	95	94	-1%	Yes
280O	Aylesbury - Oxford	91	95	5%	Yes
2OX_I	Kidlington - Oxford	45	39	-14%	Yes
2OX_O	Oxford - Kidlington	46	40	-13%	Yes
2SX_I	Kidlington - Oxford	45	39	-14%	Yes
2SX_O	Oxford - Kidlington	28	27	-3%	Yes
35I	Abingdon - Oxford	46	41	-11%	Yes
35O	Oxford - Abingdon	33	31	-6%	Yes
3I	Rose Hill - Oxford	25	25	0%	Yes
3O	Oxford - Rose Hill	33	30	-10%	Yes
5I	Blackbird Leys - Oxford	39	38	-3%	Yes
5O	Oxford - Blackbird Leys	39	35	-9%	Yes
66I	Southmoor - Oxford	25	27	8%	Yes
66O	Oxford - Southmoor	25	29	14%	Yes

Transit line	Description	Timetable	Modelled JT	% Difference	Passed?
6I	Lower Wolvercote - Oxford	16	15	-7%	Yes
6O	Oxford - Lower Wolvercote	16	15	-5%	Yes
8I	Barton - Oxford	39	38	-2%	Yes
8O	Oxford - Barton	32	34	7%	Yes
98C	Didcot - Orchard Centre	15	15	1%	Yes
M10C	Milton Park - Didcot Parkway	25	24	-3%	Yes
P300I	Peartree - Redbridge	27	32	19%	No
P300O	Redbridge - Peartree	27	29	7%	Yes
P400I	Thornhill - Seacourt	39	41	5%	Yes
P400O	Seacourt - Thornhill	37	42	13%	Yes
P500I	Water Eaton - Oxford	14	18	27%	No
P500O	Oxford - Water Eaton	15	18	23%	No
P700I	Kidlington - Headington	50	48	-4%	Yes
P700O	Headington - Kidlington	59	51	-14%	Yes
P800I	Thornhill - John Radcliffe	12	13	7%	Yes
P800O	John Radcliffe - Thornhill	18	15	-16%	No
P900I	Thornhill - Headington	14	15	6%	Yes
P900O	Headington - Thornhill	13	14	9%	Yes
S1I	Carterton - Oxford	67	60	-10%	Yes
S1O	Oxford - Carterton	68	62	-9%	Yes
S2I	Brize Norton - Oxford	70	78	11%	Yes
S2O	Oxford - Brize Norton	62	71	14%	Yes
S3I	Chipping Norton - Oxford	62	53	-14%	Yes
S3O	Oxford - Chipping Norton	62	55	-12%	Yes
S4I	Banbury - Oxford	83	89	7%	Yes
S4O	Oxford - Banbury	80	84	5%	Yes
S5AI	St George - Oxford	63	62	-2%	Yes
S5AO	Oxford - St George	65	64	-1%	Yes
T1I	Watlington - Oxford	63	62	-1%	Yes
T1O	Oxford - Watlington	57	59	3%	Yes
U1I	Harcourt Hill - Wheatley	57	56	-1%	Yes
U1O	Wheatley - Harcourt Hill	57	55	-3%	Yes
vilI	Bicester Village Shuttle	7	6	-8%	Yes
vilO	Bicester Village Shuttle	7	6	-14%	Yes
X13I	Abingdon - John Radcliffe	50	43	-13%	Yes
X13O	John Radcliffe - Abingdon	52	45	-13%	Yes
X2I	Wallingford - Oxford	80	77	-4%	Yes
X2O	Oxford - Wallingford	79	77	-3%	Yes
X30I	Wantage - Oxford	45	50	10%	Yes
X30O	Oxford - Wantage	50	53	6%	Yes
X39I	Wallingford - Oxford	43	44	3%	Yes
X39O	Oxford - Wallingford	35	35	0%	Yes
X3I	Abingdon - Oxford	23	28	21%	No

Transit line	Description	Timetable	Modelled JT	% Difference	Passed?
X3O	Oxford - Abingdon	25	25	-2%	Yes

Rail station-station journey times were coded to match the timetable.

The coding of bus and rail services was verified against the timetables in terms of service frequencies and stopping patterns.

7.4. Bus Assignment Validation

The bus assignment validation made use of observed data on passengers crossing three cordons, as described in Section 7.1.1. The following criteria were used for the link count comparison:

- Observed count > 150: Modelled flows within 25% of observed flows
- Observed count < 150: GEH < 5

Comparisons between modelled and observed link flows are presented below in Table 7-5 to Table 7-14. The validation to link counts is very good, with over 85% of links meeting the criteria in each of the time periods. A summary of the validation achieved is given in Table 7-5 below.

Table 7-5 Bus Assignment Validation Summary

Cordon and time period	% of links meeting criteria
AM Peak	
Oxford Cordon Inbound	78%
Oxford Cordon Outbound	78%
Bicester Cordon Inbound	100%
Bicester Cordon Outbound	100%
Didcot Cordon Inbound	100%
Didcot Cordon Outbound	100%
AM Peak All Cordons	89%
Inter Peak	
Oxford Cordon Inbound	89%
Oxford Cordon Outbound	89%
Bicester Cordon Inbound	100%
Bicester Cordon Outbound	100%
Didcot Cordon Inbound	100%
Didcot Cordon Outbound	100%
Inter Peak All Cordons	94%
PM Peak	
Oxford Cordon Inbound	78%
Oxford Cordon Outbound	78%
Bicester Cordon Inbound	100%
Bicester Cordon Outbound	100%
Didcot Cordon Inbound	100%
Didcot Cordon Outbound	100%
PM Peak All Cordons	89%

Table 7-6 AM Peak Link Validation - Oxford Cordon

Location	Direction	Model Link	Observed (Passengers)	Modelled (Passengers)	% Difference	GEH	Passed?
Blackbird Leys Road, NW of Sandy Lane West	IN	21000-20730	787	706	-10%		Yes
B480 Garsington Road, SE of John Smith Drive	IN	21145-85137	3	27		6.2	No
Horspath Driftway, SE of Awgar Stone Road	IN	20510-85131	1	0		1.4	Yes
A420 London Road, E of Lyndworth Close	IN	16009-20601	763	681	-11%		Yes
A4165 Banbury Road, S of A40	IN	20151-20155	857	873	2%		Yes
A4144 Woodstock Road, S of Wolvercote Rbt	IN	16020-20175	321	334	4%		Yes
A420 Botley Rd, W of Seacourt Car Park	IN	20240-20245	859	580	-32%		No
A4144 Abingdon Rd, S of Weirs Lane	IN	20071-20070	536	503	-6%		Yes
Cowley Road, North of Oxford Eastern Bypass	IN	20830-21295	57	94		4.3	Yes
Blackbird Leys Road, NW of Sandy Lane West	OUT	20730-21000	328	203	-38%		No
B480 Garsington Road, SE of John Smith Drive	OUT	85137-21145	14	35		4.2	Yes
Horspath Driftway, SE of Awgar Stone Road	OUT	85131-20510	41	18		4.2	Yes
A420 London Road, E of Lyndworth Close	OUT	20601-16006	497	447	-10%		Yes
A4165 Banbury Road, S of A40	OUT	20155-20151	390	392	1%		Yes
A4144 Woodstock Road, S of Wolvercote Rbt	OUT	20175-16020	48	85		4.5	Yes
A420 Botley Rd, W of Seacourt Car Park	OUT	20245-20240	277	338	22%		Yes
A4144 Abingdon Rd, S of Weirs Lane	OUT	20070-20071	173	243	40%		No
Cowley Road, North of Oxford Eastern Bypass	OUT	21295-20830	42	49		1.0	Yes

Table 7-7 AM Peak Link Validation - Bicester Cordon

Location	Direction	Model Link	Observed (Passengers)	Modelled (Passengers)	% Difference	GEH	Passed?
B4030, West of A4095	IN	40215-30025	0	0		-	Yes
Fringford Road, North of A4095	IN	30110-30130	4	2		1.2	Yes
A4421, North of A4095	IN	30120-30015	51	43		1.2	Yes
A41, East of Bicester Southern Bypass	IN	40435-30010	8	8		0.0	Yes
A41, between B4030 Vendee Drive and B4030 Oxford Road	IN	68137-30088	77	101		2.5	Yes
Fringford Road, North of A4095	OUT	30130-30110	1	1		0.0	Yes
A4421, North of A4095	OUT	30015-30120	17	9		2.2	Yes
Launton Manor Farm	OUT	30170-30100	0	1		1.4	Yes
A41, East of Bicester Southern Bypass	OUT	30010-40435	11	13		0.6	Yes
A41, between B4030 Vendee Drive and B4030 Oxford Road	OUT	30088-68137	152	153	1%		Yes
A4095, North of Chesterton	OUT	30025-30086	0	6		3.5	Yes

Table 7-8 AM Peak Link Validation - Didcot Cordon

Location	Direction	Model Link	Observed (Passengers)	Modelled (Passengers)	% Difference	GEH	Passed?
B4493, West of Didcot	IN	85368-50105	57	53		0.5	Yes
Milton Road	IN	66320-50065	52	94		4.9	Yes
A4130, East of B4016	IN	50220-50221	19	21		0.4	Yes
B4493, West of Didcot	OUT	50105-85368	64	60		0.5	Yes
Milton Road	OUT	50065-66320	318	285	-10%		Yes
A4130, East of B4016	OUT	50221-50220	29	26		0.6	Yes

Table 7-9 Inter Peak Link Validation - Oxford Cordon

Location	Direction	Model Link	Observed (Passengers)	Modelled (Passengers)	% Difference	GEH	Passed?
Blackbird Leys Road, NW of Sandy Lane West	IN	21000-20730	329	270	-18%		Yes
B480 Garsington Road, SE of John Smith Drive	IN	21145-85137	0	6		3.5	Yes
Horspath Driftway, SE of Awgar Stone Road	IN	20510-85131	17	1		5.3	No
A420 London Road, E of Lyndworth Close	IN	16009-20601	523	416	-20%		Yes
A4165 Banbury Road, S of A40	IN	20151-20155	354	391	10%		Yes
A4144 Woodstock Road, S of Wolvercote Rbt	IN	16020-20175	132	115		1.5	Yes
A420 Botley Rd, W of Seacourt Car Park	IN	20240-20245	423	393	-7%		Yes
A4144 Abingdon Rd, S of Weirs Lane	IN	20071-20070	222	229	3%		Yes
Cowley Road, North of Oxford Eastern Bypass	IN	20830-21295	13	36		4.6	Yes
Blackbird Leys Road, NW of Sandy Lane West	OUT	20730-21000	383	311	-19%		Yes
B480 Garsington Road, SE of John Smith Drive	OUT	85137-21145	1	20		5.9	No
Horspath Driftway, SE of Awgar Stone Road	OUT	85131-20510	12	3		3.3	Yes
A420 London Road, E of Lyndworth Close	OUT	20601-16006	463	395	-15%		Yes
A4165 Banbury Road, S of A40	OUT	20155-20151	409	417	2%		Yes
A4144 Woodstock Road, S of Wolvercote Rbt	OUT	20175-16020	125	122		0.3	Yes
A420 Botley Rd, W of Seacourt Car Park	OUT	20245-20240	338	340	1%		Yes
A4144 Abingdon Rd, S of Weirs Lane	OUT	20070-20071	205	233	14%		Yes
Cowley Road, North of Oxford Eastern Bypass	OUT	21295-20830	27	43		2.7	Yes

Table 7-10 Inter Peak Link Validation - Bicester Cordon

Location	Direction	Model Link	Observed (Passengers)	Modelled (Passengers)	% Difference	GEH	Passed?
B4030, West of A4095	IN	40215-30025	0	1		1.4	Yes
Fringford Road, North of A4095	IN	30110-30130	3	2		0.6	Yes
A4421, North of A4095	IN	30120-30015	41	44		0.5	Yes
A41, East of Bicester Southern Bypass	IN	40435-30010	10	7		1.0	Yes
A41, between B4030 Vendee Drive and B4030 Oxford Road	IN	68137-30088	109	121		1.1	Yes
Fringford Road, North of A4095	OUT	30130-30110	4	3		0.5	Yes
A4421, North of A4095	OUT	30015-30120	21	18		0.7	Yes
Launton Manor Farm	OUT	30170-30100	0	1		1.4	Yes
A41, East of Bicester Southern Bypass	OUT	30010-40435	12	10		0.6	Yes
A41, between B4030 Vendee Drive and B4030 Oxford Road	OUT	30088-68137	93	101		0.9	Yes
A4095, North of Chesterton	OUT	30025-30086	0	3		2.4	Yes

Table 7-11 Inter Peak Link Validation - Didcot Cordon

Location	Direction	Model Link	Observed (Passengers)	Modelled (Passengers)	% Difference	GEH	Passed?
B4493, West of Didcot	IN	85368-50105	21	12		2.2	Yes
Milton Road	IN	66320-50065	36	34		0.3	Yes
A4130, East of B4016	IN	50220-50221	1	10		3.8	Yes
B4493, West of Didcot	OUT	50105-85368	28	20		1.6	Yes
Milton Road	OUT	50065-66320	27	31		0.7	Yes
A4130, East of B4016	OUT	50221-50220	4	9		2.0	Yes

Table 7-12 PM Peak Link Validation - Oxford Cordon

Location	Direction	Model Link	Observed (Passengers)	Modelled (Passengers)	% Difference	GEH	Passed?
Blackbird Leys Road, NW of Sandy Lane West	IN	21000-20730	325	221	-32%		No
B480 Garsington Road, SE of John Smith Drive	IN	21145-85137	5	21		4.4	Yes
Horspath Driftway, SE of Awgar Stone Road	IN	20510-85131	21	1		6.0	No
A420 London Road, E of Lyndworth Close	IN	16009-20601	544	544	0%		Yes
A4165 Banbury Road, S of A40	IN	20151-20155	322	350	9%		Yes
A4144 Woodstock Road, S of Wolvercote Rbt	IN	16020-20175	70	96		2.9	Yes
A420 Botley Rd, W of Seacourt Car Park	IN	20240-20245	330	319	-3%		Yes
A4144 Abingdon Rd, S of Weirs Lane	IN	20071-20070	210	235	12%		Yes
Cowley Road, North of Oxford Eastern Bypass	IN	20830-21295	30	40		1.7	Yes
Blackbird Leys Road, NW of Sandy Lane West	OUT	20730-21000	490	405	-17%		Yes
B480 Garsington Road, SE of John Smith Drive	OUT	85137-21145	0	46		9.6	No
Horspath Driftway, SE of Awgar Stone Road	OUT	85131-20510	3	1		1.4	Yes
A420 London Road, E of Lyndworth Close	OUT	20601-16006	657	603	-8%		Yes
A4165 Banbury Road, S of A40	OUT	20155-20151	965	928	-4%		Yes
A4144 Woodstock Road, S of Wolvercote Rbt	OUT	20175-16020	416	356	-14%		Yes
A420 Botley Rd, W of Seacourt Car Park	OUT	20245-20240	833	577	-31%		No
A4144 Abingdon Rd, S of Weirs Lane	OUT	20070-20071	554	555	0%		Yes
Cowley Road, North of Oxford Eastern Bypass	OUT	21295-20830	35	65		4.2	Yes

Table 7-13 PM Peak Link Validation - Bicester Cordon

Location	Direction	Model Link	Observed (Passengers)	Modelled (Passengers)	% Difference	GEH	Passed?
B4030, West of A4095	IN	40215-30025	0	5		2.8	Yes
Fringford Road, North of A4095	IN	30110-30130	1	1		0.1	Yes
A4421, North of A4095	IN	30120-30015	27	22		0.5	Yes
A41, East of Bicester Southern Bypass	IN	40435-30010	3	8		1.3	Yes
A41, between B4030 Vendee Drive and B4030 Oxford Road	IN	68137-30088	191	210	10%		Yes
Fringford Road, North of A4095	OUT	30130-30110	3	1		1.3	Yes
A4421, North of A4095	OUT	30015-30120	21	23		0.2	Yes
Launton Manor Farm	OUT	30170-30100	0	4		1.4	Yes
A41, East of Bicester Southern Bypass	OUT	30010-40435	34	21		3.6	Yes
A41, between B4030 Vendee Drive and B4030 Oxford Road	OUT	30088-68137	78	87		1.0	Yes
A4095, North of Chesterton	OUT	30025-30086	0	5		4.0	Yes

Table 7-14 PM Peak Link Validation - Didcot Cordon

Location	Direction	Model Link	Observed (Passengers)	Modelled (Passengers)	% Difference	GEH	Passed?
B4493, West of Didcot	IN	85368-50105	95	49		5.7	No
Milton Road	IN	66320-50065	243	282	18%		Yes
A4130, East of B4016	IN	50220-50221	0	9		3.7	Yes
B4493, West of Didcot	OUT	50105-85368	16	21		1.5	Yes
Milton Road	OUT	50065-66320	62	91		3.5	Yes
A4130, East of B4016	OUT	50221-50220	4	12		1.9	Yes

7.5. Rail Matrix Validation

As noted above, no screenline or cordon counts were available for rail. However, a cross-check of the scale of rail patronage at the principal stations was made against annual station usage estimates derived from ticket sale data for 2010/11.

To make the comparison, the annual patronage data was converted to estimated 12 hour demand for an average weekday using the following assumptions:

- 250 week days per year;
- Proportion of total trips on weekdays: Full tickets – 84%; Reduced tickets – 70%; Season tickets – 94%; and
- Proportion of weekday trips departing between 07:00 and 19:00: 85%.

The comparison is shown in Table 7-15. It indicates that the rail demand for the key stations is broadly of the right order.

Table 7-15 Rail Patronage Cross-Check

	Oxford	Didcot Parkway	Bicester North
Annual Boardings – Full tickets	426085	234400	116840
Annual Boardings – Reduced tickets	1843184	543379	310982
Annual Boardings – Season tickets	629723	559376	185973
Estimated 12 hour demand (average weekday)	7594	3742	1664
Modelled 12 hour demand (average weekday)	8110	4238	2040
% Difference	7%	13%	23%

7.6. Rail Assignment Validation

Average weekday link flows (in the period 07:00-19:00) were derived from MOIRA for the main lines in the study area:

- Oxford – Banbury;
- Oxford – Bicester; and
- Oxford – Didcot/Reading.

The reason why daily flows were taken from MOIRA and not flows by period is because the period allocation is not as reliable in that it comes from ORCATS. Similar to the bus comparison, the following criteria were used:

- Observed count > 150: Modelled link flows within 25% of observed link flows
- Observed count < 150: GEH < 5.

The results of the rail assignment validation for the key lines are shown in

Table 7-16. As mentioned in section 5.6.1, the modelled flows do not consider through demand with origin AND destination outside Oxfordshire for bus and rail. The MOIRA data presented below takes into account only the rail trips with origin and/or destination in Oxfordshire.

It can be seen from the table that there is good parity between the model and MOIRA and all links pass the test specified by WebTAG.

Table 7-16 Average weekday Link Validation

Location	MOIRA (Passengers)	Modelled (Passengers)	% Difference	GEH	Passed?
Banbury – Oxford	1956	1604	-18%		Yes
Bicester – Oxford	279	331		3.0	Yes
Didcot/Reading – Oxford	6864	5949	-13%		Yes
Oxford Cordon (IN)	9099	7884	-13%		Yes
Oxford – Banbury	1983	1984	0%		Yes
Oxford – Bicester	280	353		4.1	Yes
Oxford – Didcot/Reading	6871	6372	-7%		Yes
Oxford Cordon (OUT)	9134	8709	-5%		Yes

8. Summary

8.1. Summary of Model Development

The Oxfordshire Strategic Model (OSM) is a fully multi-modal WebTAG compliant model that has been developed specifically to assess transport and land use interventions in Oxfordshire.

The OSM comprises Main Demand Model (MDM), Road Traffic Model (RTM) and Public Transport Model (PTM) elements.

The PTM element represents bus and rail travel within Oxfordshire and the surrounding area during an AM Peak hour, average Inter Peak hour and PM Peak hour on a typical day in 2013.

8.2. Summary of Standards Achieved

The OSM PTM has been validated to observed data comprising flows derived from ETM bus ticketing data, newly-collected onboard bus counts, boarding and alighting estimates derived from MOIRA data, newly-collected rail platform counts and link flows derived from MOIRA. A high standard of validation has been achieved for both the bus and rail elements, as detailed in Chapter 7.

8.3. Assessment of Fitness for Purpose

It is considered that the OSM PTM is fit for the purpose of assessing interventions in the Oxfordshire area covered in the detailed modelled area.

Appendices

Appendix A. Bus Segment Time Calculations

The total journey time for a bus service is calculated by summing the times on each link segment along its route:

$$\sum(BusLinkTime + BusTurnTime)$$

where *BusTurnTime* is the time taken for a bus to turn at a junction.

The link and turn times are calculated using inputs from the RTM. Table A-1 shows the attributes in the SATURN model that are imported into the EMME model.

Table A-1 SATURN/EMME Attributes

SATURN Code	Filename	EMME Attribute	Description
2033	*.blk	@bol	Bus Only Lane Marker
4023	*.clk	@clkp	Congested Link time
1633	*.ctu	@tup	Congested Turn Time
1803	*.flk	@flkp	Free Flow Link Time

The congested link time is used when the bus mixes with general traffic. The free flow link time is for buses using a bus-only lane. The bus only lane marker is used to differentiate within EMME which link time is used. The turn time is added to the link time to provide the total journey time.

However, there are some additional complexities that need to be incorporated into the calculation to ensure an accurate representation of the journey time, namely:

- Where there are a large number of other users of the bus lane, such as taxis or high occupancy vehicles, the benefits of the bus lane will be diluted. The magnitude of the effect depends upon who is able to use the bus lanes, and the proportion of traffic this entails.
- The additional priority at junctions resulting in the installation of Selective Vehicle Detection (SVD) will not be recognised within SATURN. Therefore a calculation of the likely effect of additional bus priority is necessary.
- Delays to bus run time occurring through boarding and alighting. Typical boarding times per passenger are as follows[11]:
    - 3 seconds (where majority of tickets are off-vehicle);
    - 6 seconds (where a high proportion involve cash transactions);
    - 9 seconds (where almost all ticketing involves cash transactions and change-giving).
    - alighting times are typically 1 to 1.5 seconds per person11. Therefore alighting times may also have a bearing on journey times, although not as dramatic an impact as boarding.

These impacts are reflected by the model through factoring bus journey times accordingly. Additional attributes within EMME are used to calculate bus journey times as shown in Table A-2.

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[11] The Demand for Public Transport – TRL Report 593, 2004

Table A-2 Additional EMME Attributes

EMME Attribute	Description
@svd	Marker for SVD at signalised junctions
@bsd	Bus Stop Density. Number of bus stops per km

@bsd was set at 2.83 for links in urban areas and 1.7 for links in rural areas.

@svd = 1 if there is selective vehicle detection for buses at a given node (signalised junction). Note that for the base year model, no information was available about junctions with SVD, so @svd was set =0 for all nodes.

A.1.1. Link Time Calculation

The following formula was used to calculate the bus journey time on links:

Bus Link time = Adjustment Factor * (Link time + Link length*BSD*delay)

Where:

- Link time = SATURN congested link time (if no bus lane), or is SATURN free-flow link time (if a bus lane exists)
- BSD = Bus Stop Density (Number of bus stops per km), set at 2.83 for links in urban areas and 1.7 for links in rural areas. Note that these global bus stop densities are effectively adjusted for different parts of the network via the adjustment factor (see below).
- Delay = 20 seconds to allow for boarding / alighting
- Adjustment factor = a factor calibrated for each link such that the modelled bus journey times give a good approximation to timetabled times

Buses do not stop at every stop on their route if there are no boarders or alighters for that stop. Equally, some stops may have a longer boarding time than 20 seconds. The adjustment factor (calibrated on a link by link basis) enables journey times to be adjusted for different parts of the network, for example taking account of busier and less busy bus stops. The calculation therefore gives appropriate overall journey times and generalised cost skim matrices for the demand model.

A.1.2. Turn Time Calculation

The following formula is used to calculate the bus delay at turns:

Bus turn time = Turn time factor * SATURN turn time

However, there are a number of complications to this formula, depending on the presence of a bus lane that leads up to the stop line and if SVD exists. Little information exists as to the effects on turn times for buses at such facilities. The figures in Table A.2 are considered a best estimate.

Table A-3 Assumed Effect of Bus Priority on Turn Times

Bus priority measure		Factor on turn time
Bus Lane	SVD	
N	N	1
Y	Y	0.05
Y	N	0.15
N	Y	0.90

No information was available on the location of SVD at junctions for the base year model. However, the mechanism may be used to model the impact of introducing it in forecast mode.

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