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South East Wales Transport Model

Mode-destination model estimation

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Preface

This report has been produced for Llywodraeth Cymru / the Welsh Government. It documents the development of travel demand models for the South East Wales transport model. Mode-destinations models have been estimated for eight home-based tour purposes and for non-home-based tours and detours.

While the primary audience for the document is the Welsh Government, it may be of wider interest for transport researchers and transport planners involved in transport demand forecasting and strategic planning.

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Two other related reports have been produced. The first documents the development of travel frequency models, and the second covers the implementation of the variable demand model components and the 'pivoting' process that together are used to forecast changes in transport demand across the South East Wales region.

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Abbreviations

CBD	Central Business District
EB	Employer's Business
FMA	Fully Modelled Area
HB	Home-Based
HI	Household Interview
LOS	Level-Of-Service
MD	Mode-Destination
NHB	Non-Home-Based
NTEM	National Trip End Model
NTS	National Travel Survey
OD	Origin-Destination
PA	Production-Attraction
PD	Primary Destination
PRISM	Policy Responsive Integrated Strategic Model
PT	Public Transport
PTP	Personalised Travel Planning
SD	Secondary Destination
SEWTM	South East Wales Transport Model
VOT	Value of Time
WG	Welsh Government

1. Introduction

This report documents the development of the mode-destination (MD) models that form part of the South East Wales Transport Model (SEWTM). The South East Wales mode-destination models were developed by transferring the mode-destination models developed for the PRISM West Midlands model (PRISM) to South East Wales. Local South East Wales data collected by the Welsh Government (WG) as part of a Personalised Travel Planning (PTP) project were used to support this methodology.

The remainder of this document is structured as follows:

Chapter 2 sets out the key modelling assumptions, with an explanation of the modelling approach, and definitions of the model base year, travel purposes, modes and time periods modelled.

Chapter 3 introduces the PRISM model and presents the transfer methodology, setting out the theory underlying the approach and illustrating how it has been implemented in this context to allow the PRISM models to be transferred to the South East Wales context.

Chapter 4 details the model inputs. It describes the PTP data from which observed mode-destination choice information has been taken, level-of-service and monetary cost information that has been supplied from the 2015 highway and public transport (PT) networks and attraction data used to represent the attractiveness of destination zones.

Chapter 5 documents the model specifications, detailing both the PRISM model specifications that provided the starting point for the model transfer, as well as the adjustments that have been made to the models so that they are applicable to the South East Wales context.

Chapter 6 describes the model results and validation. The key model results presented are the scales obtained for each model transfer that provide a measure of the fit of the PRISM models in the South East Wales context. To validate the models, implied values-of-time, elasticities and trip length distributions have been analysed.

Finally, Chapter 7 summarises the MD model development and makes some recommendations for future work.

2. Modelling assumptions

This chapter sets out the key modelling assumptions used to define the scope of the PRISM (Policy Responsive Integrated Strategy Model) models that have been transferred to the South East Wales context. It starts by setting out the tour-based modelling approach, describing how travel has been represented using a combination of home-based (HB) tours and non-home-based (NHB) tours and detours. The model base year is defined, and then the travel purposes and modes that have been represented in the models are specified, drawing on analysis of the local Personalised Travel Planning (PTP) data.

2.1. Tour-based approach

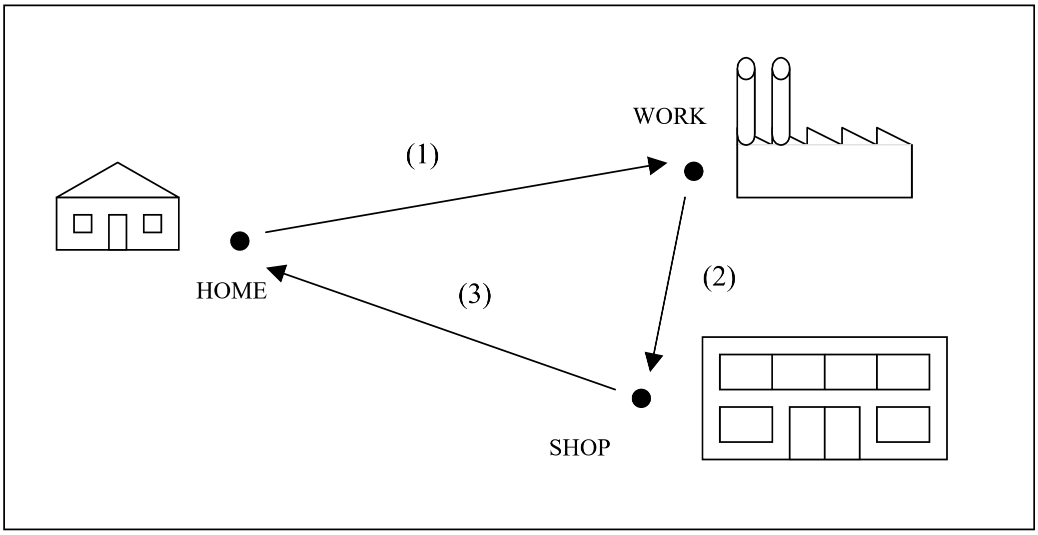
2.1.1. Home-based tours

The unit of analysis for home-based travel is the *home-based tour*. An HB tour is a series of linked trips starting and finishing at the traveller's home. The tour-based approach has a number of advantages over traditional trip-based approaches:

- Tour-based approaches model the choice of mode and destination as a function of network conditions on both the outward and return legs of the tour, whereas trip-based approaches model each leg independently.
- Tour-based approaches model the choice of mode for the entire tour, reflecting that if an individual drives to work they are highly likely to drive home again. Because trip-based approaches model each leg independently, the relationship between outward and return leg modes is usually ignored.
- Similarly, tour-based approaches model the choice of destination for the entire tour, i.e. the outward leg arrives at the same location that the return leg originates from. This linkage is not present in trip-based approaches.
- In modelling time period choice, tour-based approaches explicitly account for the time needed at the destination to carry out the activity appropriate to the trip purpose, e.g. work or shopping.
- NHB travel can be directly linked to the HB travel that occurs as part of the same trip chain in a tour-based approach. By contrast, in a trip-based approach NHB trips typically are forecast independently of HB travel and therefore linkages such as the use of the same travel mode for HB and NHB travel are often lost.

When a traveller makes a direct trip from the home to an out-of-home destination and back home again, determining the purpose of the tour is straightforward. However, if two or more out-of-home destinations are visited, it is necessary to define the *primary destination* (PD) in order to define the main purpose of the tour. This problem is illustrated in Figure 1.

Figure 1. Tour example



In Figure 1, a worker travels directly to work in the morning, but on the way home they divert to the shops. In this example either the workplace or shopping destination could be the PD.

To determine the PD in cases where more than one out-of-home destination is visited, the following purpose hierarchy was employed:

1. Work
2. Employer's business
3. Education
4. Other purposes.

In the example given in Figure 1, work is higher in the hierarchy than shopping and so the work location forms the PD and work is specified as the purpose of the tour. If there are ties after applying the purpose hierarchy then the destination at which the most time was spent is taken as the PD.[1] If there were still ties after the purpose hierarchy and maximum time criteria were applied, then of the tied destinations the destination furthest from the home was taken as the PD. If there were still ties after the purpose hierarchy, maximum time and maximum distance criteria were applied, then the first tied destination visited was taken as the PD (this only happened in a few cases).

The trip from the home to the PD is termed the *outward leg* and the trip from the PD back to the home is termed the *return leg*. If both outward and return legs are observed in the data, then the tour is described

[1] For example, in the trip chain home–shopping–shopping–home, both non-home destinations are at level four in the purpose hierarchy and so some further criteria are required to determine which of the two shopping locations that were visited forms the primary destination.

as a *full tour*. It is assumed in the HB modelling that the traveller makes a direct trip between the home and PD for both tour legs, so that in the example shown in Figure 1 the detour to the shopping destination is not represented as part of the tour; however, detours are modelled as NHB trips and in this case a NHB detour would represent the additional travel associated with the trip to the shopping destination. It should be noted that 85 per cent of the tours made in South East Wales involve direct trips to/from the PD, and do not involve any detours.

If only an outward leg or a return leg is observed, then the tour is referred to as an *outward half tour* or a *return half tour*. Some half tours are observed in the data, i.e. chains of trips that start outside the home and return to home, or chains of trips that leave home but do not return in the 24-hour period in which the survey is undertaken. However, half tours form a low percentage of the data[2] and are therefore not included in the mode-destination models on the basis that higher levels of error are associated with their purpose, mode and other information. To ensure that the total volume of travel predicted by the models is consistent with that observed in the local data, outward half tours *are* included in the frequency models that are documented separately in the frequency report.

The process used to identify the samples of HB tours and NHB trips from the local data is termed *tour building*. The tour building analysis is documented in full in Appendix A.

2.1.2. Non-home-based trips

Only NHB trips associated with full HB tours have been used for the development of the NHB mode-destination models (thus HB half tours are not included in the NHB modelling).

Linked trips that were made during the course of an HB tour but did not depart from or arrive at home were defined as NHB trips. The travel associated with these trips can be modelled within the tour-based approach in two ways:

1. PD-based tours, i.e. a series of linked trips starting and finishing at the same PD, for example if an individual makes a lunchtime trip to the shops (and back to work) during their work day.
2. NHB detours made during the outward or return legs of HB tours, i.e. a single trip to or from the PD, for example if an individual makes a diversion on their trip back home to pick up a child from school.

These two cases are illustrated by the examples illustrated in the following figures. In Figure 2, trips (2) and (3) form the PD-based tour. In Figure 3, trip (2) forms the NHB detour, and the HB tour is modelled as trip (1) plus a direct movement from work back to the home location (indicated by the dotted line in Figure 3).

[2] Just 2.5 per cent of the tours observed in the HI data were half tours.

Figure 2. PD-based tour example

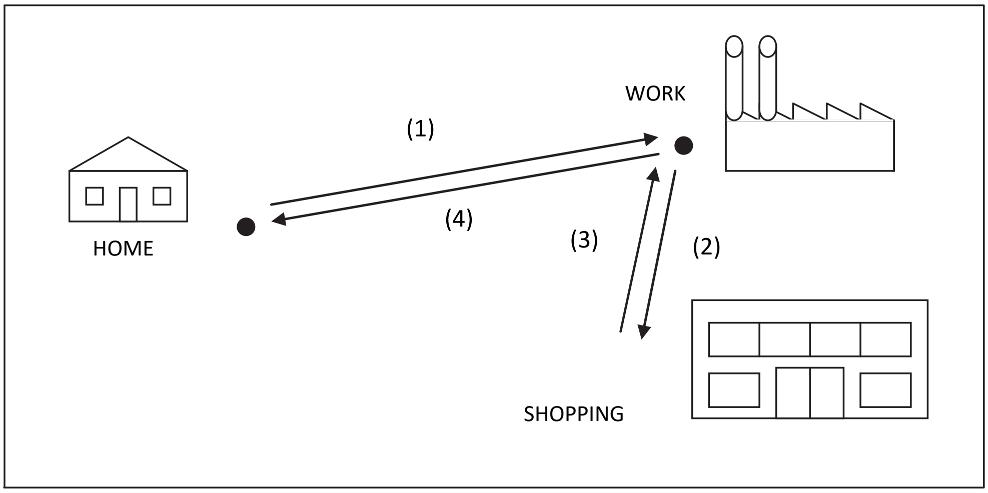
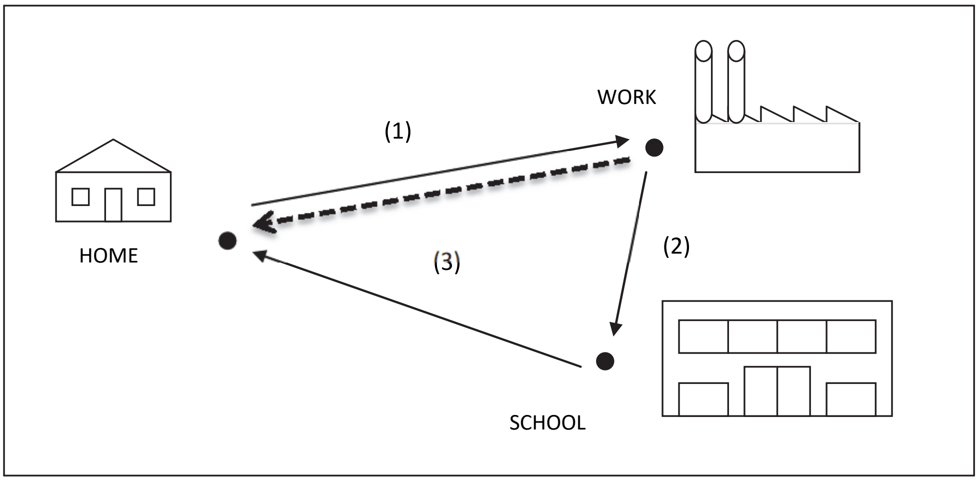


Figure 3. NHB detour example



In case 1, the purpose of the PD-based tours was determined by identifying a *secondary destination* (SD). Most PD-based tours comprised a direct return to the PD (such as PD–EB[3]–PD for which the SD was readily determined): these are referred to as *simple tours*. However, in some cases chains of three or more trips were observed (such as PD–other–EB–PD). In these cases the SD was identified based on the same rules used for identifying the PD. These are referred to as *complex tours*, and for these only direct return travel between the PD and SD is modelled. Separately modelling each of the constituent trips that form complex tours would add significant complexity to the modelling and is not justified by the low volumes of complex tours.

The purpose for detours (case 2) was also determined by identifying the purpose at the SD. Most NHB detours comprised a direct trip to or from the PD, such as home–serve passenger-PD or PD-serve passenger-home, for which the SD was directly determined. In cases where chains of three or more trips

[3] EB denotes Employer's Business.

were observed, such as home–serve passenger–shop–PD, the SD was identified based on the same rules used for identifying the PD.

Taking the detour example given in Figure 3, the observed trip pattern is home–work–school–home. The modelling approach models a direct return tour to the PD, i.e. home–work–home, and the detour from the PD to the SD, i.e. work–school. The assumption is that on average the distances PD–home and SD–home will be approximately equal and thus modelling work-home rather than school–home for the return leg gives a reasonable approximation of the actual pattern of travel observed.

2.2. Base year

The base year for the model is 2015 and therefore the network models that have been developed to represent conditions on the highway and public transport networks are representative of travel conditions in 2015. Similarly, 2015 attraction data used to represent the attractiveness of different destination alternatives has been assembled.

The local choice data that was available for this project was collected in 2011 and 2013 rather than in 2015. This issue is discussed further in Section 4.1.

2.3. Purposes

The mode-destination models have been developed using the PRISM purpose definitions, with eight different travel purposes distinguished:

- Commuting
- Home–business
- Home–primary education
- Home–secondary education
- Home–tertiary education
- Home–shopping
- Home–serve passenger
- Home–other travel.

As for PRISM, six NHB purposes have been used for the mode-destination modelling that are directly linked to HB tours:

- PD-based work–work tours
- PD-based work–other tours
- PD-based other–other tours
- Work–work detours
- Work–other detours
- Other–other detours.

PD-based work locations can be either the individual's main workplace (so forming part of a commute tour) or a business location (so forming part of a home–business tour). The SD locations for work must always be business locations and so the distinction between work and other SDs ensures that the differences in values of time (VOT) between business and other travel are properly represented in the treatment of NHB travel.

Section 4.1 compares the purpose shares in the local data to those observed in the HI data used to develop the PRISM West Midlands model.

2.4. Modes

Six modes have been represented in the mode-destination models:

1. Car driver
2. Car passenger
3. Bus (including school bus)
4. Train
5. Cycle
6. Walk.

Seven modes are represented in the PRISM model, the difference being the use of three PT modes in PRISM: train, metro and bus. Metro does not exist as a mode in the SEWTM model for the 2015 base year and so has not been represented in model transfer. However, when the models are used in application there is a need to predict demand for new PT alternatives. These are Bus Rapid Transit (BRT), Light Rail and New Heavy Rail (NHR), where rolling stock with improved comfort and acceleration is used in place of the existing heavy rail. The relative attractiveness of these new PT alternatives in the South East Wales context has been investigated using a stated preference exercise (Mott MacDonald 2015a). The model implementation report discusses how the results from the stated preference exercise have been used to introduce the new PT modes into the mode-destination model structures used for forecasting.

2.5. Time periods

Four time periods have been distinguished in the assignment and mode-destination models:

- AM peak: 07:00 – 09:30
- Inter-peak: 09:30 – 15:30
- PM peak: 15:30 – 18:00
- Off-peak: 18:00 – 07:00.

The AM peak, inter-peak and PM peak periods were determined by Mott MacDonald based on analysis of highway and PT survey data collected for this project between May and July 2015 (Mott MacDonald 2015b). To model 24-hour demand, off-peak has been defined for the mode-destination modelling work as the period between the end of the PM peak and the start of the AM peak the following day.

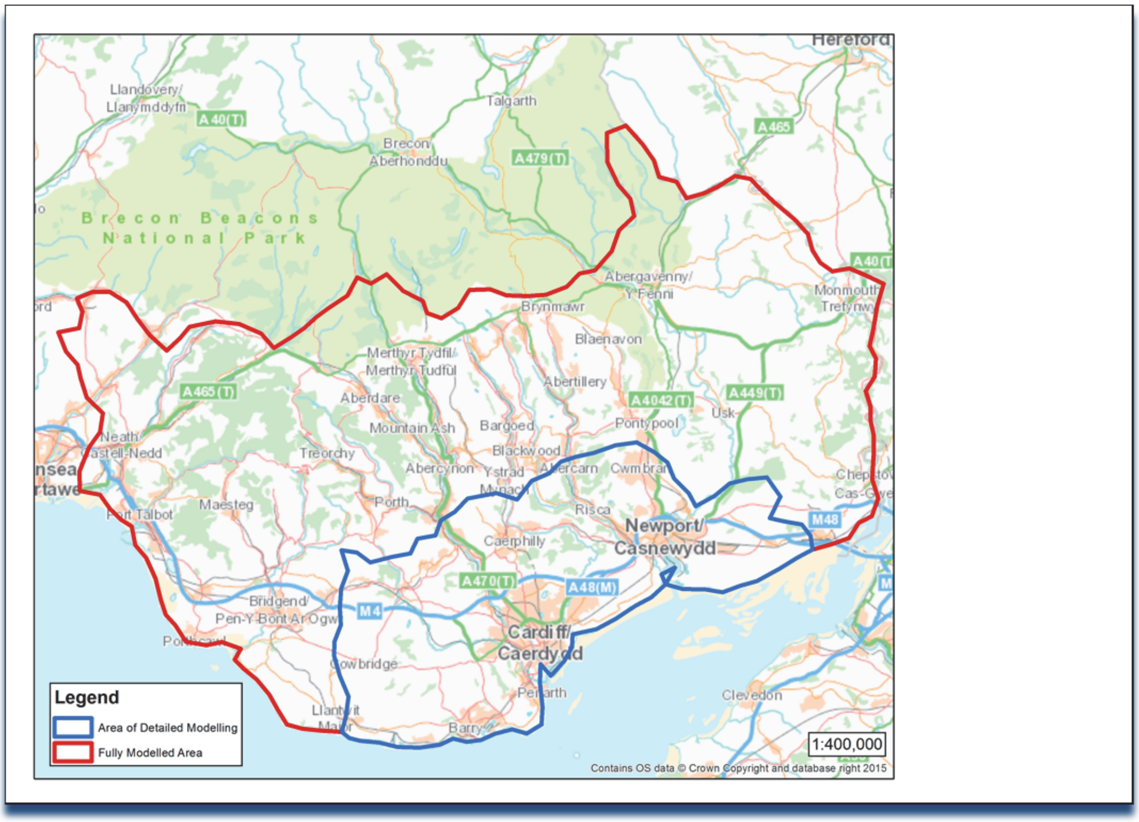
2.6. Zoning

The zone system that Mott MacDonald has generated for this project uses a total of 1,001 zones. The system distinguishes the detailed model area focussed around Cardiff and Newport, the rest of the fully modelled area and external zones. Table 1 presents a summary of the zone numbering and some headline statistics associated with the zone system (Mott MacDonald 2016). Figure 4 illustrates the geographical area covered by the detailed and fully modelled areas.

Table 1. Summary of SEWTM zone system

Model area	Zone number range	Number of zones	Population (2015)	
			Total	Zonal mean
detailed modelled area	1–687	687	823,695	1,199
rest of fully modelled area	1001–1277	277	821,985	2,957
external zones covering the rest of Wales	2001–2016	16	1,455,700	90,881
external zones covering England and Scotland	3001–3021	21	60,144,500	2,864,021
Total		1,001	63,245,790	63,183

Figure 4. Extent of detailed and fully modelled areas



From Table 1 it can be seen that the detailed and fully modelled areas combined cover over half of the population of Wales. All of the choice data used for the model transfer was collected in the detailed model area. However, in application of the model the mode-destination models will be used to predict the choices of residents of both the detailed and fully modelled areas. This approach is analogous to that used in PRISM, where the behavioural model parameters were estimated from households in the core area (the seven West Midlands metropolitan districts) but were used to predict the behaviour of residents of both the core and intermediate model areas, where the intermediate area is a ring around the core areas. Both the core and intermediate areas lie within the wider West Midlands region.

3. Spatial transfer approach

This chapter begins by explaining what is meant by the concept of spatial transfer and why the approach was appropriate for developing the travel demand models for South East Wales. Although the primary motivation was the limited local data available to support the model transfer, cost effective and timely delivery of an operational model were also important considerations.

3.1. Why use spatial transfer?

Koppelman and Wilmot (1982) provide the following definition of model transfer and the related concept of model transferability:

> First, we define transfer as the application of a model, information, or theory about behaviour developed in one context to describe the corresponding behaviour in another context. We further define transferability as the usefulness of the transferred model, information or theory in the new context.

Thus in a model transfer behaviour parameters are estimated using data collected in the *base context* to predict behaviour in the *transfer context*.

Model transfers may be spatial (for example from one region to another), temporal (applying a model estimated at one point at time to predict historical or future behaviour), or both (like most travel demand models). The focus of this report is the *spatial transfer* of models developed in the West Midlands, the base context, to predict behaviour in South East Wales, the transfer context. However, it should be noted that when the models are applied to forecast future behaviour an implicit assumption is made that the behavioural parameters in the model are transferable over time. Thus the application of the spatially transferred models, documented in the implementation report, will in turn involve a temporal transfer.

If a model is transferred from one context to another without any adjustment to the model scale (sensitivity) or model parameters then this is termed a *naïve transfer*. A number of mode choice studies in the 1980s investigated *transfer scaling* (Gunn et al. 1985; Koppelman et al. 1985), whereby scaling terms (applied to the utility equations) were estimated to account for differences in model scale (sensitivity of model response) between the base and transfer contexts, as well as new alternative specific constants for the transfer context. These studies demonstrated that the transfer scaling technique yielded substantially more transferable models than naïve transfer of the base parameters, and that the estimation of new mode constants in the transfer context was important in realising the improvement in model transferability.

In a mode choice spatial transfer, differences in the mode constants between base and transfer contexts will follow from differences in a number of unmeasured effects between the two contexts, such as perceptions of comfort, safety, reliability and other effects for public transport modes, and differences in levels of hilliness for active modes unless these differences are directly captured in the level-of-service (LOS) information.[4]

The key advantage of the transfer scaling technique is that it allows a detailed model estimated using a larger dataset collected in the base context to be transferred using a smaller dataset collected in the transfer context. Given that disaggregate mode-destination models rely on household interview surveys that are expensive and time consuming to carry out, spatial transfer offers the potential for mode-destination models to be developed quickly and cost effectively provided there is sufficient data in the transfer context.

In this study, it was not possible to collect new data within the timescales available for model development, and therefore an approach was required that made best available use of existing data. The local choice data, which is summarised in Section 4.1, does not contain sufficient sample sizes to allow South East Wales mode-destination models to be developed. However, the sample sizes and level of available socio-economic data allow the PRISM mode-destination models to be transferred to the South East Wales context. Therefore this was the methodological approach set out in the proposal for this work and it is the one that has been adopted for the mode-destination model development work.

3.2. Methodological approach

In this study, a two-step approach to the model transfer was undertaken. Firstly, for some travel purposes, the PRISM mode-destination model specifications were modified to drop specific constants and disability terms identified for the West Midlands that cannot be defined using the South East Wales data. Specifically, the home–shopping and home–other travel modes contain positive constants on car passenger modes, and negative constants on active modes (walk and cycle), reflecting differences in mode use for travellers with a disability that impacts on mobility. Secondly, the PRISM mode-destination models were transferred to the South East Wales context.

This section starts by providing an overview of the PRISM mode-destination models before going on to detail the transfer process.

3.2.1. PRISM West Midlands mode-destination model structures

Mode-destination models were estimated in PRISM for eight HB and six NHB travel purposes, as detailed in Section 2.3.

The PRISM mode-destination models represent seven modal alternatives:

- Car driver

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[4] Demand matrices are 'assigned' to network models that are built using packages such as VISUM. The assignment software determines routing from the network, and then from the assigned networks level-of-service (LOS) information is determined between each origin and destination. Travel times and distances are outputted from the highway networks models: for public transport modes more information is provided on access and egress components as well as various components of the public transport journey such as in-vehicle time and number of interchanges.

- Car passenger
- Train
- Metro
- Bus
- Cycle
- Walk.

The metro mode has been dropped for the South East Wales context because no metro services operated in the region in the 2011 base year; otherwise the same six modes are represented.

The destinations in the PRISM context relate to the PRISM West Midlands model zone system, and as such offer a high level of spatial detail in the West Midlands region and less detail elsewhere.

For some travel purposes, the PRISM models incorporate time period choice for car driver as part of the mode-destination model structure, specifically commuting, home–business, home–shopping, home–serve passenger and home–other travel. Furthermore, for commute, home–shopping and home–other travel, models of train access mode and access station are integrated into the mode-destination model structure.

The development of the West Midlands mode-destination model specifications is detailed in full in Fox et al. (2014b). In summary, these models define a utility function that represents the attractiveness for each mode-destination alternative for a given individual. The utility function for a given mode-destination alternative may include:

1. An attraction term representing the attractiveness of the destination zone, for example total employment for the commute model.
2. For motorised modes, a term representing the monetary cost of the journey.
3. Terms representing the level-of-service of the journey, such as travel time or distance, and out-of-vehicle components for PT modes.
4. Car availability terms (influencing the availability of a car for driving and passenger journeys).
5. Other socio-economic terms, in most cases capturing variations in modal preferences, for example by age, gender and adult status groups.
6. A mode constant, reflecting preferences for modes, over and above the measured characteristics.
7. Destination constants, reflecting preferences for modes, over and above the measured characteristics captured in the first six sets of terms.

The terms in the utility equation can be seen as equivalent to, but more comprehensive than, generalised cost measures, in that they include contributions from socio-economic and other effects as well as the monetary cost and level-of-service components that would form part of a typical generalised cost measure.

Prior to transferring the models to the South East Wales context, some minor modifications were made to the PRISM model specifications: mode and destination constants specific to the West Midlands context have been omitted, and some terms capturing the impact of disability on mode choice have also been omitted because the terms cannot be defined using the local data. The modifications are summarised in Section 6.2.

3.2.2. Transfer to the South East Wales context

Following the modifications described above, the mode-destination utilities in the PRISM models can then be defined as:

$$U_{m,d}^{PRISM} = \boldsymbol{\beta}^{PRISM}\mathbf{X}^{WM} + \beta_m^{WM} \qquad (3.1)$$

where: $U_{m,d}^{WM}$ are the utilities for mode-destination alternative *md*

$\boldsymbol{\beta}^{PRISM}$ is a vector of PRISM mode-destination model parameters

$\mathbf{X}^{WM}$ is a vector of data observed in the West Midlands

β_m^{SEW} is a mode constant estimated for the West Midlands context

For some travel purposes, the utility for the car driver model includes time period constants.[5] In these cases Equation (3.1) is extended to:

$$U_{card,d,tp}^{WM} = \boldsymbol{\beta}^{PRISM}\mathbf{X}^{WM} + \beta_{card}^{PRISM} + \beta_{tp}^{WM} \qquad (3.2)$$

where: β_{tp}^{WM} is a time period constant for the West Midlands context

The mode-destination utilities in the South East Wales transfer context have been defined as:

$$U_{m,d}^{SEW} = \phi^{SEW}\sum\nolimits_n \boldsymbol{\beta}^{PRISM}\mathbf{X}_n^{SEW} + \beta_m^{SEW} \qquad (3.3)$$

where: $U_{m,d}^{SEW}$ are the utilities for mode-destination alternative *md*

ϕ^{SEW} is the transfer scale parameter, estimated across the *n* modes

$\boldsymbol{\beta}^{WM}$ are the West Midlands mode-destination model parameters that are transferred

$\mathbf{X}^{WM}$ is a vector of data observed in South East Wales

β_m^{SEW} is a mode constant estimated for the South East Wales context

Purposes where car driver time period choice is modelled, Equation (3.3) is extended to:

$$U_{card,d,tp}^{SEW} = \phi^{SEW}\sum\nolimits_n \boldsymbol{\beta}^{WM}\mathbf{X}_n^{SEW} + \beta_{card}^{SEW} + \beta_{tp}^{SEW} \qquad (3.4)$$

where: β_{tp}^{SEW} is a time period constant for the South East Wales context

Thus the key output from the transfer estimation process, for a given travel purpose, is the transfer scale parameter. Ideally, a set of South East Wales destination constants would also have been estimated for some travel purposes, however due to data issues this was not possible. This issue is discussed further in Section 5.1.

A value of one for the transfer scale parameter indicates that the level of error in the PRISM and South East Wales contexts is equal. A value of zero indicates that the West Midlands model parameters provide

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[5] For those purposes where the car driver utilities do not vary over time periods, weighted average costs over time periods are used.

no information about the South East Wales mode-destination choices, so that the error associated with the transferred parameters is infinite. Values greater than one are theoretically possible, but in general we would expect values less than one given that the detailed model specifications were developed to best fit travel patterns in the West Midlands. A further consideration is that, in model application, a value greater than one would result in higher sensitivity to changes in utility than in the West Midlands context, and this could result in the models predicting higher levels of response to policy tests because the implication of a scale parameter greater than one is that the transferred model is *more* sensitive to cost changes in the transfer context than in the base context. This outcome was judged by the estimation team to be undesirable.

4. Input data

This chapter provides a description of the input data that have been used for model development. Five sets of data are described:

1. *Choice data* – observed mode and destination choices in South East Wales alongside person- and household-level information.
2. *Highway data* – detailing the time, distance and monetary cost of travel associated with travel by modes that use the highway network, both within South East Wales and between South East Wales and the rest of Wales as well as England and Scotland.
3. *Public transport data* – detailing LOS and the monetary cost of travel associated with travel by modes that use the highway network, both within South East Wales and between South East Wales and the rest of Wales as well as England and Scotland.
4. *Attraction data* – land-use data that are used to represent the attractiveness of each destination zone in the mode-destination choice models.
5. *Income data* – data supplied from the land-use model database that forecast mean incomes by home ward and household type.

These five sets of data are described in Sections 4.1 to 4.5.

4.1. Choice data

4.1.1. Personalised Travel Planning data

The local choice data were collected as a part of a Personalised Travel Planning (PTP) project funded by the Welsh Government (WG). Larger household interview (HI) samples were collected for the Cardiff and Penarth areas, and the same survey forms were also used to conduct smaller surveys in Caerphilly, Pontypridd and Barry. The volume of HI data available is summarised in Table 2.

Table 2. Summary of PTP area sample sizes

PTP area	Year	Households	Persons	Trips
Cardiff PTP (before)	2011	548	1,380	3,987
Cardiff PTP (after)	2013	575	1,313	3,726
Caerphilly	2013	168	427	1,208
Pontypridd	2013	197	430	1,169
Barry[6]	2013	260	607	1,724
Total		1,748	4,157	11,814

A particular feature of the PTP data that is unusual compared to other datasets is the way origin and destination information are recorded in the trip database. For travel within a given PTP area, both origins and destinations are coded at the ward level using a set of wards presented to respondents. However, for travel to destinations outside the PTP area, the survey simply recorded that the destination was outside the PTP area. This could mean another destination in South East Wales, or a destination elsewhere in Wales or indeed to somewhere in England or Scotland. Thus while the survey recorded short-distance travel within the region it does not give insights into the destination of longer trips. The implications of the destination coding issues for the model estimation structure are discussed in Section 5.1. The sets of wards presented to respondents in each of the four PTP areas are listed in Appendix B.

The local PTP data were processed to provide HB tours and associated NHB travel following the principles of the tour-based approach set out in Section 2.1. The results from this 'tour building' process are documented in full in Appendix A.

Given that the agreed methodological approach for the mode-destination modelling was to transfer the PRISM West Midlands models to the South East Wales context, once the South East Wales tours had been built analysis was undertaken to examine the sample sizes to check that they would support a model transfer.

4.1.2. Home-based purposes

Table 3 presents a comparison of the total number of HB tours observed in the 2011–2013 SEWTM data with the samples in the PRISM 2011 HI data. Both HI samples were undertaken on weekdays in school term time.

[6] Two sets of survey were undertaken in Barry, one in spring and the other in autumn.

Table 3. Comparison of HB tour samples

South East Wales data 2011 & 2013			PRISM West Midlands data 2011		
PD purpose	Tours	Share	PD purpose	Tours	Share
commute	1,166	23.3%	commute	4,215	30.2%
employer's business	13	0.3%	employer's business	537	3.8%
education	515	10.3%	education	2,903	20.8%
serve passenger	497	9.9%	serve passenger	1,779	12.7%
shopping	1,056	21.1%	shopping	1,865	13.4%
personal business	169	3.4%	other	2,661	19.1%
leisure	1,582	31.6%			
commercial	3	0.1%			
Total	5,001	100.0%	Total	13,960	100.0%

The overall volume of HB tours in the South East Wales data is about one-third of that observed for the West Midlands. However, as discussed in Chapter 3, a key advantage of the transfer approach is that the transfer sample can be significantly smaller than the base sample used to develop the underlying behavioural model parameters and therefore the sample size for the South East Wales data is not in itself problematic for the model transfer.

The share of mandatory travel – commute, employer's business and education purposes – is much lower in the South East Wales data compared to the West Midlands data. Furthermore, while the South East Wales commute and education sample sizes are sufficient to allow the PRISM models to be transferred, the employer's business sample is not. For frequency modelling, the approach used to overcome the lack of employer's business data was to use information from version 7.1 of the National Trip End Model (NTEM). However, the NTEM information would not support a mode-destination model transfer. Given the lack of employer's business data in the South East Wales data to support a model transfer where scale parameter and mode-specific constants for South East Wales were estimated, the PRISM employer's business mode-destination model has been transferred directly without any adjustments to the model specification.

Corresponding to the differences for mandatory travel, the total share of discretionary travel – serve passenger, shopping and other purposes – is higher in the SEWTM HI data (66 per cent of total tours) than the PRISM HI data (45 per cent of total tours). Other purposes, which include leisure, personal business and commercial tours, account for more than half of the discretionary tours in the SEWTM HI data.

One concern was that the balance between mandatory and discretionary travel in the data from South East Wales could somehow be biased. This could then manifest itself in biased tour frequency models because the local frequency models would not reflect overall trip-making levels across South East Wales.

Another was that the PRISM West Midlands data is biased (however, the both the sample sizes and data quality were higher in that context). However, the frequency report (Dunkerley et al. 2018) demonstrates that when the SEWTM frequency model predictions were compared to those from NTEMv7.1 for South East Wales, there was a good level of consistency in the predictions for work-related and non-work-related travel. Thus the differences in the purpose distributions seem to relate to other factors, such as differences in the characteristics of the individuals in the region.

4.1.3. Non-home-based purposes

As discussed in Section 2.1.2, two types of NHB travel can occur in the course of HB tours: PD-based tours and NHB detours. Separate purposes have been defined for each of these types of NHB travel. Consistent with PRISM, NHB purposes are defined separately for travel that is work-related (to the main workplace, the not usual workplace, or to an employer's business location) and for all other travel.

Three purposes have been defined to model PD-based tours, taking advantage of the purpose hierarchy that assigns work-related destinations as the PD whenever they occur:

1. PD-based tours made from work-related PDs to work-related SDs
2. PD-based tours made from work-related PDs to other SDs
3. PD-based tours made from other purpose PDs to other SDs.

Three further purposes have been defined to model NHB detours:

1. NHB detours made during work-related PD tours to work-related SDs
2. NHB detours made during work-related PD tours to other purpose SDs
3. NHB detours made during other purpose PD tours to other purpose SDs.

The volume of PD-based tours from the PTP data available for the model transfer is summarised in Table 4. The rows define the primary destination PD, the columns the SD data.

Table 4. PD-based tours by simplified purpose

	Primary destination purpose	Secondary destination purpose					
		Work-related		Non-work-related		Total	
Outward detour	Work-related	53	28.2%	87	46.3%	140	74.5%
	Non-work-related			48	25.5%	48	25.5%
	Total	53	28.2%	135	71.8%	188	100.0%

Three-quarters of detours are made as work-related PDs. However, these are more likely to be made for non-work-related purposes, and overall nearly three-quarters (71.8 per cent) of PD-based tours are made for non-work-related travel.

The sample sizes of detours available for the transfer of the PD-based models are summarised in Table 5.

Table 5. NHB detours by origin and destination purpose

	Origin purpose	Destination purpose					
		Work-related		Non-work-related		Total	
Outward detour	Work-related	37	7.4%	102	20.3%	139	27.7%
	Non-work-related			362	72.3%	362	72.3%
	Total	37	7.4%	464	92.6%	501	100.0%
Return detour	Work-related	53	9.4%	145	25.8%	198	35.2%
	Non-work-related			364	64.8%	364	64.8%
	Total	53	9.4%	509	90.6%	562	100.0%
Total	Work-related	90	8.5%	247	23.2%	337	31.7%
	Non-work-related			726	68.3%	726	68.3%
	Total	90	8.5%	973	91.5%	1,063	100.0%

In the case of work-related HB tours, detours are more likely be made during the return legs. This is consistent with our experience in other studies and is an intuitive finding (for example, an individual may return home from work via the shops or the gym). For non-work-related HB tours, the numbers of detours observed are similar in both directions.

More detailed analysis of the NHB travel observed in the PTP data is presented in Appendix A.

4.2. Cost data

4.2.1. Highway

Highway LOS skims were supplied by Mott MacDonald. The LOS information for the base year (2015) was generated for the fully modelled area, as well as external zones.

The LOS skims were supplied for four time periods, and for each time-period the following LOS attributes for each origin–destination (OD) pair were provided:

- Free flow travel time
- Congested travel time
- Distance between OD
- Toll cost.

However, because of the difference in zoning between the PTP data and the SEWTM model system these skims cannot be directly used for mode-destination model estimation. A composite choice structure in which the fully modelled area (FMA) zones are nested within wards allows this possibility. This issue is discussed further in Section 5.1. No LOS information[7] is provided for intrazonal OD pairs (i.e. for OD pairs with the same origin and destination).

4.2.2. Vehicle operating costs

Vehicle operating costs, which include both fuel and non-fuel costs, are calculated based on the procedure set out in the November 2014 version of TAG Unit A1.3.

Fuel costs

The fuel costs are estimated using a function of the form:

$$C = a/v + b + cv + dv^2$$

where:

C is the fuel cost in pence per km

v average speed in kilometres per hour (km/h)

a, b, c, d are parameters defined for each vehicle category and also for an average vehicle

Table A.1.3.12 and Table A.1.3.13 in the TAG data book (Autumn 2015) provide a list of parameters for an average car, for work and non-work purposes respectively. The parameters by year and purpose for an average car[8] are summarised in Table 6.

Table 6. Fuel cost parameters for an average car by year and purpose, values in 2010 prices

Work	a	b	c	d
2011 (HI data)	91.43583	5.625972	-0.03297	0.000369
2013 (HI data)	82.88934	5.355804	-0.03319	0.000356
2015 (Model base)	61.55384	4.163189	-0.02704	0.00028
Non-work	a	b	c	d
2011(HI data)	109.723	6.751091	-0.03956	0.000443
2013 (HI data)	99.4672	6.426719	-0.03983	0.000427
2015 (Model base)	73.8646	4.995425	-0.03244	0.000336

In model estimation, the fuel or energy cost formula has been applied to calculate the car costs for the outward and return legs of tours, and for NHB detours. The average speed is calculated from the distance and congested travel time information from the highway network LOS for each OD pair for the tour leg or NHB detour. The highway LOS information varies according to the four model time periods, and so

[7] In application, the LOS for intrazonal OD pairs will be imputed by RAND Europe by talking half the value of nearest zone to provide an approximation. This approach is consistent with WebTAG unit 3.10.2.

[8] Based on fuel category, i.e. petrol, diesel and electric and the corresponding fleet mix, the average car values are derived. The average car values are now directly reported in the TAG data book.

for tour legs and detours made in peak periods where there is more congestion, average speeds are lower, and the fuel cost per kilometre is higher if the average speed falls below 60km/h.

4.3. Public transport

The public transport data were developed by Mott MacDonald, who have summarised their work in a note that is presented in Appendix C.

4.4. Attraction data

The choice of attraction variable for a particular travel purpose is part of the PRISM model specifications that has been transferred to the South East Wales context. For some travel purposes, more than one attraction (size) variable is used to represent the attractiveness of destination zones.

Table 7 summarises the attraction variables used for each model purpose.

Table 7. Size variables by model purpose

Purpose	Attraction variables
commuting	total employment
home–business	total employment
home–primary education	primary education enrolments
home–secondary education	secondary education enrolments
home–tertiary education	tertiary enrolments total employment
home–shopping	retail employment
home–serve passenger	population total employment primary education enrolments secondary education enrolments
home–other travel	population total employment service employment retail employment
PD-based tours, work-related PD to work-related SD	total employment
PD-based tours, work-related PD to other SD	population total employment service employment retail employment
PD-based tours, other PD to other SD	population total employment service employment retail employment
detours during work-related tours to work-related SDs	total employment
detours during work-related tours to other SDs	population total employment service employment retail employment
detours during other tours to other SDs	population total employment service employment retail employment

For home–tertiary education, tertiary enrolments are used as the attraction variables for full-time students, and total employment is used as the attraction variable for all other adults. Adults other than full-time workers are included in the model because a significant minority of tours were observed to be made by these persons, for example a full-time worker attending an evening class.

4.5. Income data

The PTP data did not collect any income information and therefore an alternative source of data was required. As part of the wider project to develop the South East Wales Transport Model, DSC assembled a 2015 land-use database. This provided mean household incomes for combinations of home zone, defined at the ward level, and 33 household categories. The 33 household categories were defined from a combination of household type and socioeconomic level detailed in Table 8.

Table 8. Household categories in DSC income data

Household type	Socio-economic level			
	1	2	3	4
single person household, person aged under 50	1	9	17	25
single person household, person aged 50–64	2	10	18	26
single person household, person aged 65 and over	3	11	19	27
single adult household, with one or more dependent children	4	12	20	28
two or more adult household, both or all aged under 50, no dependent children	5	13	21	29
two or more adult household, one or more aged 50 and over, no dependent children	6	14	22	30
two or more adult household, with one or more dependent children	7	15	23	31
two or more adult household, all aged 65 and over	8	16	24	32
two or more full-time student household, no dependent children	33			

The five socio-economic levels are defined in Table 9.

Table 9. Socio-economic levels used in DSC household categories

Socio-economic level	Occupation (by SOC of Household Reference Person)
1	1. Managers, directors and senior officials 2. Professional occupations
2	3. Associate professional and technical occupations 4. Administrative and secretarial occupations 6. Caring, leisure and other service occupations
3	5. Skilled trades occupations 7. Sales and customer service occupations
4	8. Process, plant and machine operatives 9. Elementary occupations
5	Other, undefined, or no occupation

5. Model specification

This chapter summarises the PRISM model specification developed from data specific to the West Midlands. With the exception of some modifications to the local mode and destination constants, the model specification estimated from the West Midlands data has been transferred to South East Wales.

5.1. Treatment of destinations

To represent destination choice, a bespoke destination choice structure had to be developed to take account of the unusual destination coding used in the PTP survey forms (described in Section 4.1.1). The model estimation structure takes account of the fact that four different PTP regions were sampled: Barry, Caerphilly, Cardiff and Pontypridd. The destination choice structure then varies for a particular individual depending on which of these four regions they reside in. The choice structure illustrated in Figure 5 is for an individual interviewed in the Cardiff PTP survey.

Figure 5. Destination choice structure

Three nested destination choices are presented in Figure 5 for a resident of Cardiff:

1. *Within vs outside PTP area choice* – the choice whether to travel to a Cardiff or non-Cardiff destination.
2. *Ward level choice* – for individuals who chose to travel within the Cardiff area, the choice of Cardiff ward w_j where there are J Cardiff wards in total; for individuals who chose to travel outside of Cardiff a single alternative was represented because the non-Cardiff ward they travel to is not observed.
3. *Zonal level* – no choice information is observed at this level, but the model structure represents the C model zones that cover the Cardiff area, and the O model zones that cover the rest of mainland Great Britain (including, for the Cardiff example, the Barry, Caerphilly and Pontypridd zones).

Model structures have been developed using the same principles for individuals interviewed in the Barry, Caerphilly and Pontypridd PTP surveys. Table 10 summarises the number of wards and destination alternatives represented for each of the four PTP areas.

Table 10. Summary of wards and zones in each PTP area

PTP area	Wards in PTP area	Zones in PTP area	Zone outside PTP area
Barry	8	46	955
Caerphilly	7	50	951
Cardiff	33	296	705
Pontypridd	10	22	979

The names of the wards that lie within each PTP area are detailed in Appendix B.

The lack of destination information for travel outside of a specific PTP area meant that it was not possible to estimate destination-specific constants from the data. For example, a central destination Cardiff constant could be defined from a set of wards covering the central area. However, for individuals in the Barry, Caerphilly and Pontypridd surveys who travel outside their PTP area, we do not know whether or not they travelled to Central Cardiff and as a result no destination constants can be defined.

5.2. Mode and time period alternatives

This section defines the mode and time period alternatives and specific conditions that govern the availability of the possible mode-destination-time period alternative combinations.

5.2.1. Mode alternatives

As discussed in Section 2.4, up to six mode alternatives are represented in the South East Wales models:

- Car driver
- Car passenger

- Bus
- Train
- Cycle
- Walk.

Because children of primary and secondary school age are too young to drive, the car driver mode is not represented for the home–primary education and home–secondary education travel purposes. Some modes were set to be unavailable because no data was observed in the PTP data (specifically no train tours were observed for home–primary education and no cycle tours were observed for home–secondary education). Furthermore, for some of the NHB purposes, some modes are not represented due to limited sample sizes both in the West Midlands HI data used to develop the model specification and in the PTP data used to transfer the models to South East Wales.

Table 11 summarises which travel modes are represented in the South East Wales models by travel purpose. As noted earlier, the PRISM model contained a mode for metro travel, but this mode is not represented in the transferred models because no metro services existed in South East Wales when the 2011 and 2013 PTP surveys were undertaken.

Table 11. Main modes represented by travel purpose

Purpose	Car driver	Car pass.	Bus	Train	Cycle	Walk
commute	✓	✓	✓	✓	✓	✓
home–business	✓	✓	✓	✓	✓	✓
home–primary education		✓	✓		✓	✓
home–secondary education		✓	✓	✓		✓
home–tertiary education	✓	✓	✓	✓	✓	✓
home–shopping	✓	✓	✓	✓	✓	✓
home–serve passenger	✓	✓	✓			✓
home–other travel	✓	✓	✓	✓	✓	✓
PD-based tours, work-related PD to work-related SD	✓	✓	✓			✓
PD-based tours, work-related PD to other SD	✓		✓			✓
PD-based tours, other PD to other SD	✓	✓				✓
detours during work-related tours to work-related SDs	✓	✓	✓	✓		✓
detours during work-related tours to other SDs	✓	✓	✓	✓		✓
detours during other tours to other SDs	✓	✓	✓	✓	✓	✓

5.2.2. Time period alternatives

With the exception of home–primary and home–secondary education, where car driver is not available, and home–tertiary travel, which accounts for a small fraction of home–based travel, the PRISM model specifications for HB purposes represent time period (TP) choice for car driver, whereas for NHB travel where there is less choice data available TP choice is assumed to be fixed. Table 12 summarises how TP choice has been represented for those travel purposes where car driver is modelled.

Table 12. Treatment of car driver time period choice by purpose

Purpose	Treatment of car driver time period choice
commuting	modelled
home–business	modelled
home–tertiary education	assumed fixed
home–shopping	modelled
home–serve passenger	modelled
home–other travel	modelled
PD-based tours, work-related PD to work-related SD	assumed fixed
PD-based tours, work-related PD to other SD	assumed fixed
PD-based tours, other PD to other SD	assumed fixed
detours during work-related tours to work-related SDs	assumed fixed
detours during work-related tours to other SDs	assumed fixed
detours during other tours to other SDs	assumed fixed

The 13 alternatives that are represented in the time period choice models are detailed in Table 13. Cells that are highlighted in beige are time period combinations that are chronologically impossible given that the models represent 24-hour demand.

Table 13. Time period alternatives

Outward time period	Return time period				
	off-peak (early)	AM peak	inter-peak	PM peak	off-peak (late)
off-peak (early)	1	2	3	4	1
AM peak		5	6	7	8
inter-peak			9	10	11
PM peak				12	13
off-peak (late)					1

The highway assignment models represent a single off-peak period and so there is no difference in the modelled highway LOS between the off-peak (early) and off-peak (late) periods. Therefore, TP alternative 1 is any of three possible combinations of off-peak outward and off-peak return that are shown in Table 13.

The PRISM models that are used in application also incorporate models of access mode and station choice for train and metro modes; this structure is referred to as the park-and-ride model. Correspondingly, the park-and-ride sub-model was only introduced to the SEWTM mode-destination model structure when the models were implemented and is therefore documented in the SEWTM model implementation report (Fox et al. 2016).

5.2.3. Specifying alternative availability

At the lowest level in the choice structure, the destination alternatives represented in the models are the 1,001 SEWTM model zones and therefore there are a total of 6,006 mode-destination alternatives for those travel purposes where all six modal alternatives are represented. However, as discussed in Section 5.1, a complex destination structure was required for model estimation to take account of the level of destination coding information.

For travel purposes where TP choice is modelled, there are 13 TP alternatives for car driver and up to five other modes are represented without TP choice. For those purposes where all six modal alternatives are represented there a total of (13 + 5)*1001 = 18,018 mode-destination-time period alternatives represented in the model estimation structures.

The availability of these mode and mode-time period alternatives varies according to the home location and car availability of the individual. It is defined according to the following conditions:

- Car driver is available if the traveller holds a driving licence and there is at least one car in the household. There is no restriction based upon destination alternative because it is possible to drive to all destination zones represented in the model.
- Car passenger is available to all travellers. It is assumed that persons in households without a car can still travel as a car passenger with a person from outside their household. Of the 2,040 car passenger tours observed in the 2009–2012 HI, 213 (10.4 per cent) were made by individuals from households without a car.
- Bus is available to travellers if a bus service exists for the origin-destination pair in question, i.e. the bus-only LOS gives a non-zero bus IVT for both the outward and return legs of the tour.
- Train is available to travellers if a train service exists between the origin-destination pair in question, i.e. the train LOS gives a non-zero train IVT for both the outward and return legs of the tour. Note that multi-modal journeys involving both bus and train are represented as using the 'train' mode.
- Cycle is available to all travellers provided that the round trip is less than 60 km in length, consistent with the condition applied to cycle when the PRISM models were estimated.
- Walk is available to all travellers provided that the round trip is less than 30km in length, consistent with the condition applied to walk when the PRISM models were estimated.

There is an additional check for each destination alternative that there is a non-zero attractive variable, e.g. that for people making a commute journey that there is employment in the specific destination. For purposes such as commuting and business this check is always passed because there is at least one job in each model zone; however, for education purposes in particular this check does restrict the availability of the 1,001 destination choice alternatives. The attraction variables in the modelling are discussed in more detail in Section 4.4 above.

5.3. Treatment of cost

5.3.1. Base year adjustment

Because the PTP data that have been used for the model transfer were collected in 2011 and 2013 (Table 2), the costs in the models need to reflect 2011 values and prices, even though some of the cost data that has been assembled in 2015 prices, as that is the base year for SEWTM.

Costs in 2013 and 2015 prices were deflated to 2011 prices using the following equation:

$$Cost_{2011}^{SEW} = Cost_{y}^{SEW} * \left(\frac{CPI_{2011}}{CPI_{y}} \right) \tag{5.1}$$

where: $Cost_{2011}^{SEW}$ is the cost deflated back to 2011 prices

$Cost_{y}^{SEW}$ is the cost in year *y*

CPI_{2011} and CPI_{y} are the CPI factors for years 2011 and *y* respectively

The Consumer Price Index (CPI) factors that were used in Equation (5.1) to deflate costs are summarised in Table 14.

Table 14. CPI factors

Year *y*	CPI factor
2011	119.6
2013	126.1
2015	128.0

A further consideration is that the PRISM cost parameters are in 2011 *values* as well as 2011 prices. For the PTP choice data collected in 2011 no adjustment is necessary. However, for the PTP choice data collected in 2013 a real income adjustment is required to account for income growth between 2011 and 2013. This adjustment is necessary because growth in real incomes leads to reductions in cost sensitivity, all other things being equal. Fox (2015)[9] developed an approach for applying the cost adjustment that drew on a review of relevant literature and empirical tests on mode-destination models developed for Toronto and Sydney. Extending Equation (5.1) to take account of this cost adjustment, the equation that was used was to adjust costs to account for both inflation and real income growth was:

[9] See Section 5.1.1 of Fox (2015), http://etheses.whiterose.ac.uk/10479/

$$Cost_{2011}^{SEW} = Cost_{2013}^{SEW} * \left(\frac{CPI_{2011}}{CPI_{2013}} \right) * \left(\frac{I_{2011}}{I_{2013}} \right) \tag{5.2}$$

where: I_{2011} is a measure of mean income in 2011

I_{2013} is a measure of mean income in 2013

5.3.2. Cost sharing between drivers and passengers

The PRISM models incorporate a *cost sharing* mechanism that allows the differential impact of changes in car costs on demand for car driver and car passenger modes to be represented. This approach was developed through testing on both the PRISM and Manchester Motorway Box projects (Fox et al. 2009).

The car cost sharing approach allocates car costs between car driver and car passenger modes using the following equations:

$$CarCost_{OD}^{CD} = \beta_{Cost} CarCost_{OD} \left[1 - \frac{S(O^{CD} - 1)}{O^{CD}} \right] \tag{5.3}$$

$$CarCost_{OD}^{CP} = \beta_{Cost} CarCost_{OD} \left(\frac{S}{O^{CP}} \right) \tag{5.4}$$

where:

β_{Cost} is the cost parameter, estimated across all modes in the model

$CarCost_{OD}$ is the total car cost including any parking costs at the destination

$CarCost_{OD}^{CD}$ is the fraction of total car cost that is represented for car driver

$CarCost_{OD}^{CP}$ is the fraction of total car cost that is represented for car passenger

S is the cost sharing factor

O^{CD} is the mean occupancy for car driver observations in the PTP data

O^{CP} is the mean occupancy for car passenger observations in the PTP data

Given that the cost sharing factors S were calibrated to best fit the PRISM data, which includes car occupancies, and that the PRISM estimation samples were significantly larger than the PTP samples (Table 3), the mean car occupancies observed in PRISM were retained in the model transfer. These mean car occupancies are summarised in Table 15.

Table 15. Mean occupancy values (from the PRISM model)

Purpose	Car driver	Car passenger
commuting	1.045	2.049
home–tertiary education	1.150	2.120
home–shopping	1.300	2.340
home–serve passenger	1.511	2.448
home–other travel	1.235	2.260
work-related PD to work-related SD tours	1.000	2.000
work-related PD to other SD tours	1.053	2.000
other PD to other SD tours	1.187	2.291

Source: Table 28, Fox et al. (2009).

5.3.3. Non-linear treatment of costs

The treatment of cost in the PRISM models is documented in full in Fox et al. (2014a). The majority of the models use a non-linear treatment of cost that provides cost damping. The approach developed has been termed the *gamma formulation*. It was developed during testing on earlier versions of the PRISM and Manchester Motorway Box models (Fox et al. 2009) and has been used successfully in a number of model systems since then.

In the gamma formulation, the cost term in the utility function is expressed as a combination of linear and logarithmic terms as follows:

$$\beta_{\cos t}\left\{\gamma.\mathrm{cost}+(1-\gamma)\log(\mathrm{cost}).\frac{\mathrm{E(cost)}}{\mathrm{E(log(cost))}}\right\} \tag{5.1}$$

where: γ, i.e. gamma, controls the relative contribution of linear and logarithmic cost

E(cost) is the mean cost

E(log(cost)) is the mean logarithmic cost

the ratio *E(cost)/E(log(cost))* ensures that linear and logarithmic cost use the same scale

E(cost) is the mean cost

E(log(cost)) is the mean logarithmic cost

the ratio *E(cost)/E(log(cost))* ensures linear and logarithmic cost use the same scale

A gamma value of one implies a purely linear cost model, i.e. no damping on monetary cost. A gamma value of zero implies a purely log cost model. In our experience low gamma values give the best balance between fit to the observed mode-destination choices, model elasticity and implied values of time. The trade-offs reached during the development of the PRISM models are documented in some detail in Section 5.1.1 of Fox et al. (2014a).

5.3.4. Impact of household income on cost sensitivity

Some of the mode-destination model specifications represent variation in cost sensitivity with household income band, and when models are applied the marginal impact of cost is lower for higher income groups. In policy terms this means that cost changes, such as changes in car costs as a result of parking charges or changes in PT fares, will have a larger impact on lower income travellers. The treatment of income for each of the PRISM travel purposes is summarised in Table 16.

Table 16. Summary of variation of cost sensitivity with income band by model purpose

Purpose	Cost sensitivity variation with HH income?
commuting	yes, four income bands
home–business	no
home–primary education	no
home–secondary education	no
home–tertiary education	no
home–shopping	yes, two bands plus income not stated
home–serve passenger	no
home–other travel	yes, three bands plus income not stated
PD-based tours, work-related PD to work-related SD	no
PD-based tours, work-related PD to other SD	no
PD-based tours, other PD to other SD	no
detours during work-related tours to work-related SDs	no
detours during work-related tours to other SDs	no
detours during other tours to other SDs	yes, three bands plus income not stated

The three HB purposes that represent variation in cost sensitivity with income band – namely commuting, home–shopping and home–other travel – together represent more than three-quarters (79.5 per cent) of the HB tours observed in the PTP data (Table 3). Income segmentation is only directly represented in one of the NHB purposes where the sample sizes for model estimation are smaller.

5.4. Socio-economic terms

In the PRISM model, travellers' preferences were found to vary across different socio-economic groups. The presence of these terms both yielded an improved fit to the base year data and enabled the models to directly represent the impact of changes in the distribution of the population over segments over time. For example, if in a given model zone incomes are forecast to rise in the future, that would follow through into a shift towards higher-income segments (which are less sensitive to cost changes than lower-income groups).

The PRISM socio-economic terms are documented in full in Fox et al. (2014a). Table 17 summarises the main socio-economic effects that are present in the models and that have been transferred to the South East Wales context. For some model purposes, parameters representing difference in mode choice for individuals with a disability that impacts upon their mobility were dropped prior to model transfer. This issue is discussed further in Section 6.1.2.

Table 17. PRISM mode-destination model car availability and socioeconomic parameters

Purpose	Car availability	Adult status	Age	Gender	Household income	Household size	Presence of children in household
commuting	√	√	√	√	√		
home–business	√	√					
home–primary education	√						
home–secondary education	√			√			
home–tertiary education	√	√				√	
home–shopping	√	√		√	√		
home–serve passenger	√			√	√		√
home–other travel	√	√	√	√	√		
work–other detours	√	√					
other–other detours	√						

It is noted that there are no socio-economic effects present in the three PD-based tour models or in the work–work detour model.

The car availability terms are key in governing the attractiveness of the car driver and car passenger alternatives, and account for the impact of:

- Household car ownership
- Individual licence holding – a pre-requisite for an individual being able to drive
- Household licence holding.

For households with cars, household car ownership and household licence holding are together used to calculate car competition terms for the car driver mode, representing the lower probability of a person with a licence being able to make a journey as a driver when there are other licence holders in the household competing for access to the car(s). For the car passenger mode, a 'passenger opportunity' term is applied when the household owns at least one car and when at least one other individual in the household owns a licence so that they can offer the individual a lift.

The car availability terms present in the models for car driver and car passenger modes are summarised in Table 18. The beige shading for home–primary education and home–secondary education has been added because car driver is not available as a mode for primary and secondary aged children.

Table 18. Car availability terms by purpose and mode

Purpose	Car driver		Car passenger				Bus		Walk
	Free car use	Car competition	Passenger opportunity	Free car use	1 car in household	2+ cars in household	0 cars in household	2+ cars in household	2+ cars in household
commuting	√	√	√	√					
home–business		√							
home–primary educ.			√			√	√		
home–secondary educ.			√		√				
home–tertiary educ.		√	√					√	√
home–shopping	√		√				√		
home–serve passenger		√	√						
home–other travel	√		√				√		
work–other detours		√							
other–other detours			√						

It is noted that in the home–shopping model, separate free car use terms are applied for 1 car and 2+ car households, and separate passenger opportunity terms are applied to the car-passenger utility for 2 person and 3+ person households.

5.5. Structural tests

The model specifications include model nesting structures that take account of differences in the relative sensitivity of mode and destination choices to cost changes, such as those that result from changes in travel time or monetary cost. The structural parameters that were estimated from the PRISM data form part of the PRISM model specification that has been transferred to the South East Wales context. A value of one for the structural parameter indicates that mode and destination choices are equally sensitive to utility changes (and are represented as a multinomial model structure). Values that tends towards zero indicate that destination choice is more sensitive to utility changes than mode choice (the TAG guidance is that this model structure is the most likely one). At the extreme, a value close to zero indicates that that there is no mode choice information in the model so that destination choice is infinitely more sensitive to utility changes than mode choice.

The structural parameters θ_{M_D} that have been estimated are summarised in Table 19. The t-ratios given in brackets are the significance of the structural parameter relative to a value of one.

Table 19. Summary of the mode-destination structural parameters

Purpose	Structure	Structural parameter θ_{M_D}	t-ratio
commuting	MNL modes and dests	1.00	*
home–business	modes above destinations	0.59	2.3
home–primary education	MNL modes and dests	1.00	*
home–secondary education	modes above destinations	0.82	1.7
home–tertiary education	MNL modes and dests	1.00	*
home–shopping	modes above destinations	0.29	19.5
home–serve passenger	modes above destinations	0.48	7.4
home–other travel	modes above destinations	0.34	13.0
PD-based tours, work-related PD to work-related SD	MNL modes and dest	1.00	*
PD-based tours, work-related PD to other SD	MNL modes and dests	1.00	*
PD-based tours, other PD to other SD	MNL modes and dests	1.00	*
detours during work-related tours to work-related SDs	modes above destinations	0.25	12.1
detours during work-related tours to work-related SDs	MNL modes and dests	1.00	*
detours during other tours to other SDs	MNL modes and dests	1.00	*

For home-based travel, the differences between the mode and destination choice sensitivities are greater for the discretionary travel purposes of shopping, serve passenger and other than for the mandatory travel purposes of commute, business and education. When the models are applied to test policy this means that for discretionary travel purposes there will a greater tendency for destination shifting rather than mode shifting relative to mandatory travel purposes. In the TAG Unit M2 guidance, the expectation is that fuel cost elasticities will be higher for discretionary travel purposes than for mandatory travel purposes, and this is consistent with a tendency for greater destination shifting than mode shifting.

6. Model results

This chapter summarises the results from the model transfers. Section 6.1 documents the West Midlands models that were used in the model transfers, and in particular covers how the West Midlands model specifications have been modified so that they are suitable for the model transfer. Section 6.2 then details the transfer of these models to the South East Wales context.

6.1. The West Midlands models

As discussed in Section 3.2, the first stage in the model transfer process was to revise the PRISM West Midlands models to remove parameters that cannot be applied in the South East Wales context given the available PTP choice data. Two sets of parameters were removed: destination effects that are specific to the West Midlands, and parameters that capture differences in mode share in the West Midlands for individuals with a disability that impacts on their mobility. These two sets of parameters are discussed below.

6.1.1. Omitting West Midlands destination effects

In the PRISM West Midlands mode-destination models, significant destination effects were identified for four of the HB purposes, namely commuting, home–shopping, home–escort and home–other travel. The destination effects that were dropped from the models for these purposes prior to transferring the latter to the South East Wales context are summarised in Table 20.

Table 20. Destination effects dropped from the West Midlands model specifications

Parameter		Commute	Home—shopping	Home—serve passenger	Home—other
CBDDest	increased attractiveness of travel to CBD destinations over and above other differences		√	√	√
CBDBus	increased attractiveness of bus for travel to CBD destinations over and above other differences		√	√	√
CBDTrain	increased attractiveness of train for travel to CBD destinations over and above other differences	√			√
CBDMetro	increased attractiveness of metro for travel to CBD destinations over and above other differences				√
ExtDest	constant to balance total tours to external destinations	√			
TrExtDest	constant to balance of total tours to external destinations	√			

The Central Business District (CBD) parameters that were dropped from the model specifications capture the additional attractiveness of travel to the CBD over and above what is represented by the attraction variables, LOS and other model parameters. Often these parameters are associated with PT modes and so capture a mode choice effect for CBD destinations whereby individuals have a preference for PT modes over and above the combined effect of high PT accessibility to CBD destinations and higher levels of congestion associated with car travel to these destinations.

For the commute model, destination effects were also added to ensure that the proportion of tours travelling to destinations external to the fully modelled areas was represented correctly. In particular, terms were added to correct for an over-prediction of train tours to areas outside the West Midlands FMA which was believed to occur as a result of the difficulties involved in capturing the average rail fares paid by travellers.

6.1.2. Omitting disability effects

The West Midlands HI data recorded disability information from all individuals and so it was possible to test whether mode choice preferences varied according to the disability of the traveller. Significant effects were identified for two of the home-based purposes. These are summarised in Table 21.

Table 21. Disability effects dropped from the West Midlands model specifications

Parameter		Home—shopping	Home other
CarPDisab	persons with a disability impacting mobility are more likely to travel by car passenger	√	√
SlowDisab	persons with a disability impacting mobility are less likely to travel by walk and cycle modes	√	√

6.1.3. Summary of the impact of modifications to the model specifications

Table 22 summarises the impact of omitting destination and disability effects on the fit of the PRISM models to the mode-destination choices observed in the West Midlands data. The fit of the data is measured using the log-likelihood (LL) measure. This measure cannot be compared across different model purposes, but it can be used to assess the impact for a given mode-destination sample of removing parameters from the model specification. It should be noted that the model specifications for the remaining four HB purposes, and all six of the NHB purposes, were transferred without any modifications to the model specifications.

Table 22. Overall impact of modifications to the PRISM West Midlands models

Purpose	Sample size	Full specification		Transferred specification		Change in degrees of freedom	Change in LL
		model	LL	model	LL		
commute	4,030	131	-28,385.8	134	-28,421.7	3	35.9
home–shopping	1,834	100	-8,742.8	104	-8,760.9	4	18.1
home–serve passenger	1,703	46	-7,492.9	47	-7,499.9	2	7.0
home–other travel	2,581	121	-16,576.4	126	-16,585.5	2	9.1

It can be seen from Table 22 that the loss of fit to the data as a result of dropping the destination and disability terms is modest.

The PRISM models that have been transferred for the eight HB and six NHB mode-destination purposes are documented in full in Appendix D. These models provide the parameters in Equation (3.1) in Section 3.2.

6.2. Transfer results

The PRISM model specifications were transferred to the South East Wales context using Equation (3.2) in Section 3.2. For each model purpose, two models were estimated, one with the scale parameter freely estimated and one with the scale parameter constrained to a value of one, referred to as 'fixed' in the results table. Table 23 summaries the scale parameters that were estimated as well as the fit of the models to the data. The t-ratios presented for the scale parameters measure their significance relative to a value of one.

Table 23. Summary of model transfer

Purpose	South East Wales sample size	Estimated scale		Model fit		Significance test	
		value	t-ratio	estimated	fixed	change in fit	signif-icant.?
commuting	1,098	0.718	12.2	-4,772.7	-4,840.0	67.4	yes
home–primary education	174	1.024	0.4	-390.9	-390.9	0.1	no
home–secondary education	151	0.930	1.2	-397.9	-398.6	0.7	no
home–tertiary education	88	0.588	9.3	-325.7	-366.7	41.0	yes
home–shopping	1,004	1.013	0.6	-3,692.6	-3,692.8	0.2	no
home–serve passenger	397	0.858	4.0	-1,590.2	-1,597.6	7.4	yes
home–other travel	1,644	1.095	4.5	-6,753.4	-6,764.1	10.7	yes
PD-based tours, work–work	17	-0.015	12.5	-64.0	-78.7	14.8	yes
PD-based tours, work–other	27	1.815	2.6	-33.0	-38.8	5.8	yes
PD-based tours, other–other	30	0.494	5.9	-109.1	-120.9	11.8	yes
detours, work–work	188	0.398	15.9	-823.9	-948.5	124.6	yes
detours, work–other	147	1.140	1.8	-506.0	-507.8	1.7	no
detours, other–other	521	1.074	2.2	-1,673.3	-1,675.9	2.6	yes

For commute, home–tertiary and home–serve passenger, scale parameters in the range 0–1 have been estimated that give a significant improvement to the fit to the South East Wales PTP data relative to a value of one. Therefore these models have been used for the model transfers. For home–primary, home–secondary and home–shopping the estimated scales are not significantly different from a value of one. Therefore for these purposes the scale parameters have been fixed to one. Finally, for home–other the scale parameter is significantly greater than one but the value is not much greater than one. It was therefore constrained to one to ensure that the model is not over-sensitive to changes in utility.

In summary, for HB purposes the transfer process has worked well. For three purposes, no significant difference in scale could be identified between the West Midlands and South East Wales contexts, which is reassuring because it demonstrates the transferability of the West Midlands parameters to South East Wales. Only for commute and home–tertiary are the scales in the South East Wales context significantly lower than one.

For the six NHB purposes there are fewer South East Wales data available for the model transfer, particularly for the three PD-based tour purposes. For PD-based work–work tours the value of the scale parameter (close to zero) implies that the sample sizes were too small to allow a model transfer, whereas for PD-based work–other tours, and for work–other and other–other detours, scale parameters greater than one have been estimated. For these four travel purposes the scale parameters have been fixed to one. However, for PD-based other–other tours and for work–work detours scale parameters significantly less than one were identified and are incorporated in the transfer.

Table 24 summarises the scale parameters in the final models that have been taken forward for implementation.

Table 24. Final values of model scale parameters

Purpose	South East Wales obs	Scale
commuting	1,098	0.718
home–primary education	174	1.000
home–secondary education	151	1.000
home–tertiary education	88	0.588
home–shopping	1,004	1.000
home–serve passenger	397	0.858
home–other travel	1,644	1.000
PD-based tours, work-related PD to work-related SD	17	1.000
PD-based tours, work-related PD to other SD	27	1.000
PD-based tours, other PD to other SD	30	0.494
detours during work-related tours to work-related SDs	188	0.398
detours during work-related tours to other SDs	147	1.000
detours during other tours to other SDs	521	1.000

The full model results from the transfer models are presented in Appendix D.

6.3. Model validation

To validate that the transferred mode-destination models respond plausibly to changes in utility and are able to replicate observed mode and destination behaviour in South East Wales, a series of validation checks have been undertaken. These are described below.

6.3.1. Model elasticities

The following elasticity validation tests have been run for four policy tests:

- A 10 per cent increase in fuel cost
- A 10 per cent increase in car time
- A 10 per cent increase in PT fares, including both cash fares and season tickets
- aA10 per cent increase in PT IVT.

The 10 per cent increases are applied uniformly across all origin–destination pairs in the estimation (PTP) sample. The elasticities are then calculated using the constant elasticity formulation:

$$E_{m,p} = \frac{\ln\left(\frac{D_{m,p}}{D_{m,b}}\right)}{\ln\left(\frac{110}{100}\right)} \quad (6.1)$$

where: $E_{m,p}$ is the elasticity for mode m under policy p

$D_{m,p}$ is the demand for mode m under policy p

$D_{m,b}$ is the demand for mode m in the base case b

It should be emphasised that the elasticities are first order only, i.e. they do not take into account crowding effects. When the models are applied iteratively, so that changes in demand impact on the supply costs, the fuel cost elasticities would be expected to be slightly lower because of network effects damping the model response. The car time elasticities will be run for one iteration only, i.e. without crowding, as per the TAG guidance.

Table 25 summarises the results from the fuel cost and car time tests for the car driver mode. No results are presented for home–primary and home–secondary education purposes because car driver is not modelled for these travel purposes. For all purposes, the percentage of demand is presented to allow the relative contribution of each individual purpose to the weighted average to be assessed.

Table 25. Car driver fuel cost and car time elasticity results

Purpose	Per cent demand		Fuel cost		Car time	
	tours	kms	tours	kms	tours	kms
commuting	28.5%	33.7%	-0.08	-0.26	-0.19	-0.58
home–business	3.5%	9.5%	-0.01	-0.12	-0.10	-1.19
home–tertiary education	1.2%	2.0%	-0.06	-0.15	-0.23	-0.72
home–shopping	18.1%	9.1%	-0.04	-0.12	-0.08	-0.82
home–serve passenger	11.1%	5.0%	-0.06	-0.38	-0.06	-0.56
home–other travel	26.2%	21.3%	-0.04	-0.11	-0.09	-0.97
PD-based tours, work–work	0.2%	0.3%	-0.24	-0.46	-0.33	-0.51
PD-based tours, work–other	0.2%	0.1%	-0.26	-0.25	-0.90	-1.79
PD-based tours, other–other	0.5%	0.9%	-0.06	-0.12	-0.11	-1.33
detours, work–work	5.0%	2.6%	-0.01	-0.28	-0.01	-0.47
detours, work–other	2.4%	1.6%	0.00	-0.15	-0.02	-0.60
detours, other–other	3.1%	13.9%	-0.02	-0.03	-0.03	-0.21
Weighted average	100.0%	100.0%	-0.05	-0.17	-0.10	-0.71

When considering purpose variation in the fuel cost kilometrage elasticity values, TAG Unit M2 states that:

> …the pattern of annual average elasticities shows values for employers' business trips near to -0.1, for discretionary trips near to -0.4, and for commuting and education somewhere near the average.

The commuting and home–business kilometrage elasticities show the expected pattern described in TAG Unit M2, with lower elasticity for home–business travel. For discretionary travel purposes, both the home–other and home–shopping models are relatively inelastic to fuel price changes, whereas the home–serve passenger model is more in line with the WebTAG guidance. Home–tertiary, which accounts for a low fraction of total car driver kilometrage, has an elasticity close to the overall average.

The weighted average elasticity of -0.17 is low relative to the -0.25 to -0.35 range indicated in WebTAG. However, it should be noted that the elasticities are generated only using information on trips in the PTP area (because we do not know the destination of trips outside of the area). Therefore the elasticities are generated from a sample of much shorter trips than average. It will be more instructive to see the elasticities from the model implementation in full.

Furthermore, it is noted that the evidence on fuel cost elasticities is quite old, and increasing incomes would suggest that fuel cost elasticities should have declined significantly.

The guidance in TAG Unit M2 around car time elasticities is simply that the model should be checked to ensure no very strong elasticities are observed, with -2.0 being given as an example value. All of the car time elasticities in Table 25 fall well within that upper elasticity bound.

Table 26 summarises the results from the fuel cost and car time tests for the car driver mode. No results are presented for the 'PD-based tours, work-related PD to other SD' purpose because public transport modes are not modelled for this travel purpose. It is noted that NHB purposes represent a much lower fraction of tours and kilometrage than the HB purposes.

Table 26. Public transport fare and in-vehicle time elasticity results

Purpose	Per cent demand		PT fare		PT in-vehicle time	
	tours	kilometres	tours	kilometres	tours	kilometres
commuting	20.9%	28.2%	-0.67	-1.17	-0.46	-0.60
home–business	1.3%	2.6%	-0.19	-0.50	-0.60	-1.64
home–primary education	0.5%	0.4%	-0.96	-1.74	-0.60	-0.60
home–secondary education	10.1%	8.5%	-0.59	-1.32	-0.31	-0.30
home–tertiary education	4.6%	8.1%	-0.46	-0.78	-0.20	-0.24
home–shopping	34.6%	24.4%	-0.29	-0.94	-0.07	-0.08
home–serve passenger	0.5%	0.4%	-0.37	-0.96	-0.50	-0.56
home–other travel	21.3%	21.6%	-0.33	-1.01	-0.10	-0.12
PD-based tours, work–other	0.2%	0.2%	-0.65	-1.61	-0.25	-0.25
PD-based tours, other–other	0.2%	0.2%	-0.43	-1.24	-0.10	-0.10
detours, work–work	4.7%	3.3%	-0.11	-0.93	-0.12	-0.16
detours, work–other	0.4%	0.3%	-0.24	-0.27	-0.24	-0.26
detours, other–other	0.7%	1.9%	-0.30	-0.54	-0.22	-0.23
Weighted average	100.0%	100.0%	-0.41	-1.02	-0.20	-0.32

TAG Unit M2 guidance is that PT fare trip elasticities should lie in the range -0.2 to -0.9. Two of the elasticities lie outside that range – home–business and work–work detours – but these purposes together account for less than 2 per cent of trips, and the overall tour elasticity of -0.41 lies well within the WebTAG range. Focusing on the HB purposes, which collectively account for 94 per cent of tours, higher elasticities are observed for commuting and education purposes, and lower elasticities are observed for discretionary travel. This is consistent with the higher mode choice sensitivity for mandatory purposes relative to discretionary purposes (see Table 19 and the surrounding discussion regarding mode and destination choice sensitivity).

6.3.2. Mode shares

The models were applied to the unweighted samples of tours used for model estimation and then the predicted mode shares were compared to those observed in the PTP data. In a multinomial mode-destination structure the predicted shares should exactly match the estimation shares.[10] However, in a nested structure with modes above destinations an exact match is not guaranteed. It should be noted that a second set of mode share validation checks were made when the models were applied to the *weighted* base year population. These mode share checks are documented separately in the implementation report.

HB purposes

Table 27. Commute mode share validation

Mode	Observed	Predicted	Difference
car driver	64.2 %	64.2 %	0.0 %
car passenger	9.5 %	10.3 %	0.8 %
train	3.7 %	3.6 %	-0.1 %
bus	4.5 %	4.3 %	-0.1 %
cycle	5.2 %	5.1 %	-0.1 %
walk	12.9 %	12.5 %	-0.4 %
Total	100.0 %	100.0 %	0.0 %

The mode shares match those observed in the PTP data to within ±1 per cent.

For home–business, there was not sufficient PTP data to extract reliable mode share information and the PRISM West Midlands model was transferred directly. Therefore no equivalent validation can be presented and instead the focus is on the validation of implemented model, which is presented in the implementation report.

Table 28. Home–primary education mode share validation

Mode	Observed	Predicted	Difference
car driver	0.0 %	0.0 %	0.0 %
car passenger	54.0 %	54.0 %	0.0 %
train	0.0 %	0.0 %	0.0 %
bus	1.1 %	1.1 %	0.0 %
cycle	0.6 %	0.6 %	0.0 %
walk	44.3 %	44.3 %	0.0 %
Total	100.0 %	100.0 %	0.0 %

The home–primary model uses a multinomial mode-destination structure and as a result the predicted mode shares match those that were observed in the PTP data exactly.

[10] This is an estimation condition that follows from the use of *m-1* mode constants for *m* modes.

Table 29. Home–secondary education mode share validation

Mode	Observed	Predicted	Difference
car driver	0.0 %	0.0 %	0.0 %
car passenger	22.5 %	22.5 %	0.0 %
train	0.7 %	0.7 %	0.0 %
bus	27.2 %	27.2 %	0.0 %
cycle	0.0 %	0.0 %	0.0 %
walk	49.7 %	49.7 %	0.0 %
Total	100.0 %	100.0 %	0.0 %

There are some very slight differences between observed and predicted mode shares for home–secondary education but these are not observable when the values are rounded to the nearest 0.1 per cent.

Table 30. Home–tertiary education mode share validation

Mode	Observed	Predicted	Difference
car driver	34.1 %	34.1 %	0.0 %
car passenger	8.0 %	8.0 %	0.0 %
train	3.4 %	3.4 %	0.0 %
bus	18.2 %	18.2 %	0.0 %
cycle	9.1 %	9.1 %	0.0 %
walk	27.3 %	27.3 %	0.0 %
Total	100.0 %	100.0 %	0.0 %

As for primary education the exact match to the observed mode shares follows from the use of a multinomial mode-destination model structure.

Table 31. Home–shopping mode share validation

Mode	Observed	Predicted	Difference
car driver	44.6 %	44.7 %	0.1 %
car passenger	15.2 %	15.1 %	0.0 %
train	0.9 %	0.9 %	0.0 %
bus	13.5 %	13.4 %	0.0 %
cycle	0.4 %	0.4 %	0.0 %
walk	25.5 %	25.4 %	-0.1 %
Total	100.0 %	100.0 %	0.0 %

The home–shopping model has a strong destination nesting parameter (θ=0.29) and so mode choice is much less sensitive than destination choice (i.e. theta is much less than one). Nonetheless the mode shares match the observed values to within ±0.1 per cent.

Table 32. Home–serve passenger mode share validation

Mode	Observed	Predicted	Difference
car driver	68.8 %	68.8 %	-0.1 %
car passenger	4.5 %	4.5 %	0.0 %
train	0.0 %	0.0 %	0.0 %
bus	0.5 %	0.5 %	0.0 %
cycle	0.0 %	0.0 %	0.0 %
walk	26.1 %	26.2 %	0.1 %
Total	100.0 %	100.0 %	0.0 %

As for shopping, the differences between observed and predicted mode shares are slight despite the relatively strong destination nesting effect (θ=0.48).

Table 33. Home–other travel mode share validation

Mode	Observed	Predicted	Difference
car driver	39.4 %	39.4 %	0.0 %
car passenger	25.0 %	24.9 %	-0.1 %
train	0.5 %	0.5 %	0.0 %
bus	4.9 %	4.9 %	0.0 %
cycle	2.2 %	2.3 %	0.0 %
walk	27.9 %	28.0 %	0.0 %
Total	100.0 %	100.0 %	0.0 %

Again the mode share differences are slight despite the strong destination nesting effect (θ=0.34).

NHB purposes

Table 34. PD-based work–work tour mode share validation

Mode	Observed	Predicted	Difference
car driver	76.5 %	76.5 %	0.0 %
car passenger	11.7 %	11.8 %	0.1 %
train	0.0 %	0.0 %	0.0 %
bus	5.9 %	5.9 %	0.0 %
cycle	0.0 %	0.0 %	0.0 %
walk	5.9 %	5.9 %	0.0 %
Total	100.0 %	100.0 %	0.0 %

Table 35. PD-based work–other tour mode share validation

Mode	Observed	Predicted	Difference
car driver	14.8 %	14.8 %	0.0 %
car passenger	0.0 %	0.0 %	0.0 %
train	0.0 %	0.0 %	0.0 %
bus	3.7 %	3.7 %	0.0 %
cycle	0.0 %	0.0 %	0.0 %
walk	81.5 %	81.5 %	0.0 %
Total	100.0 %	100.0 %	0.0 %

Table 36. PD-based other–other tour mode share validation

Mode	Observed	Predicted	Difference
car driver	16.7 %	16.7 %	0.0 %
car passenger	30.0 %	30.0 %	0.0 %
train	0.0 %	0.0 %	0.0 %
bus	0.0 %	0.0 %	0.0 %
cycle	0.0 %	0.0 %	0.0 %
walk	53.3 %	53.3 %	0.0 %
Total	100.0 %	100.0 %	0.0 %

The three detour models all have multinomial mode-destination structures and as a result observed and predicted mode shares match exactly.

Table 37. Work–work detour mode share validation

Mode	Observed	Predicted	Difference
car driver	82.8 %	82.4 %	-0.3 %
car passenger	5.7 %	6.4 %	0.7 %
train	1.1 %	1.1 %	0.0 %
bus	2.2 %	2.1 %	-0.1 %
cycle	0.0 %	0.0 %	0.0 %
walk	8.2 %	8.0 %	-0.2 %
Total	100.0 %	100.0 %	0.0 %

Table 38. Work–other detour mode share validation

Mode	Observed	Predicted	Difference
car driver	81.3 %	81.6 %	0.4 %
car passenger	7.3 %	7.5 %	0.2 %
train	1.1 %	1.4 %	0.3 %
bus	1.3 %	1.4 %	0.1 %
cycle	0.0 %	0.0 %	0.0 %
walk	9.1 %	8.2 %	-0.9 %
Total	100.0 %	100.0 %	0.0 %

Table 39. Other–other detour mode share validation

Mode	Observed	Predicted	Difference
car driver	47.2 %	47.2 %	0.0 %
car passenger	26.9 %	26.9 %	0.0 %
train	0.2 %	0.2 %	0.0 %
bus	7.3 %	7.3 %	0.0 %
cycle	0.6 %	0.6 %	0.0 %
walk	17.8 %	17.9 %	0.0 %
Total	100.0 %	100.0 %	0.0 %

7. Summary and recommendations

This report summarises the spatial transfer of the Policy Responsive Integrated Strategy Model (PRISM) from the West Midlands to South East Wales. Overall the transfer has been successful with levels of scale that are close to one, which is to say that the South East Wales mode-destination models have a similar sensitivity to cost changes to the PRISM West Midlands models after taking account of income distributions. This result is evidence that the transfer theory is sound, i.e. if you take proper account of local differences model transfer is a cost-effective and timely approach to model development.

In future, there would be value in collecting more household interviews across the South East Wales region, and drawing on our experience from the PRISM West Midlands model we'd recommend a minimum of 4,000 are conducted. This would provide a more representative evidence base for model estimation and implementation. In particular, it would allow a fuller account of spatial variation in incomes to be represented by allowing the exploration of differences in the cost sensitivity distributions between the two regions.

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Appendix A: Tour building analysis

This Appendix documents the analysis that has been undertaken to 'build' tours from the household interview (HI) data. A tour is a series of linked trips starting and finishing at the traveller's home.

Building home-based tours

The travel information collected in the HI data was recorded as trips, defined as movements between two different activity locations. An individual trip could include movements by more than one mode, and up to four modes are recorded for each trip in the HI data.

A full home-based tour is a series of linked trips starting and finishing at the individual's home. The purpose of a home-based tour was determined by identifying its primary destination (PD). Most tours (85 per cent) comprise a direct trip to the PD and a direct return home, such as home–work–home. For these **simple tours**, the PD is simply the destination travelled to on the first trip of the tour. However, for some tours more complex chains of trips were observed, such as home–education-work-home. To determine the PD for **complex tours** comprising three or more trips, the following rules were used:

1. Apply a purpose hierarchy to each non-home destination (where work is at the top of the hierarchy):
    a. work
    b. work-related business
    c. education
    d. all other purposes
2. If after step 1 there were still ties, the PD is the tied destination at which the most time was spent
3. If after step 2 there were still ties, the PD is the tied destination furthest from the individual's home
4. If after step 3 there are still ties, the PD is the first tied destination visited.

Once the PD was determined, the outward tour leg was defined as the journey from the home to the PD, and the return tour leg was defined as the journey from the PD back to the home.

It is possible to observe **half tours**, which can occur in two ways:

- Chains of trips where the origin of the first trip recorded on the survey day[11] is not the home – these are return half tours, observed at the start of the survey day, e.g. a nightshift worker returning home.
- Chains of trips that depart from the home but do not return to the home on the survey day. These are outward half tours (for example, an individual who leaves the home on the survey day to visit a friend and stays overnight at their friend's house, or a nightshift worker leaving for work).

Some half tours may be coding errors, where individuals have only recorded partial information about their trip chains.

There were a total of 11,814 trip records in the HI data available for tour building. The destination purposes of these trip records are tabulated in Table 40.

Table 40. Trip records, destination purposes for the PTP data

Destination purpose	Cardiff 2011	Cardiff 2013	Caerphilly 2013	Pontypridd 2013	Barry 2013	Total	Share
work	442	434	165	130	168	1,339	11.3%
work-related business	41	36	9	10	17	113	1.0%
education	209	189	50	41	81	570	4.8%
shopping	450	460	131	161	206	1,408	11.9%
personal business	80	85	38	28	33	264	2.2%
serve passenger	330	251	77	67	139	864	7.3%
leisure	705	680	204	226	342	2,157	18.3%
home	1,721	1,580	534	506	737	5,078	43.0%
commercial	10	11	0	0	0	21	0.2%
Total	3,987	3,726	1,208	1,169	1,723	11,814	100.0%

The 11,814 trips were processed into HB tours together with associated NHB trips, and could then be classified into one of ten categories:

- The outward leg of a simple tour (ST)[12]
- The return leg of an ST
- The outward leg of a complex tour (CT)[13]
- The return leg of a CT
- Half tours (HT), outward leg
- Half tours (HT), return leg

[11] The survey day runs from 03:30 in the morning to 03:30 on the following day.

[12] An ST has two trips: the first (the outward leg) from the home to the primary destination, the second (the return leg) from the primary destination back to the home.

[13] A CT has three or more trips, and includes at least one NHB trip.

- NHB trips, full tour – NHB trips associated with CTs
- NHB trips, outward HT – NHB trips associated with outward HTs
- NHB trips, return HT – NHB trips associated with return HTs
- NHB trips, standalone – chains of trips that cannot be associated with a HB tour.

Table 41 presents the frequency distribution of trips across these ten categories, separately for each set of the PTP data.

Table 41. Trips by tour-leg type in the PTP data

Tour Leg	Cardiff 2011	Cardiff 2013	Caerphilly 2013	Ponty-pridd 2013	Barry, spring 2013	Barry, autumn 2013	Total trips	Share of total trips
ST outward leg	1,348	1,233	436	411	296	295	4,019	34%
ST return leg	1,348	1,233	436	411	296	295	4,019	34%
CT outward leg	345	319	90	91	68	69	982	8%
CT return leg	345	319	90	91	68	69	982	8%
HT outward leg	26	22	8	10	1	12	79	1%
HT return leg	29	28	8	3	1	7	76	1%
NHB trips – full tour	529	524	132	150	116	111	1,562	13%
NHB trips – out HT	5	12	5	2	0	9	33	0%
NHB trips – ret HT	12	36	2	0	1	9	60	1%
NHB trips, standalone	0	0	1	0	0	1	2	0%
Total	3,987	3,726	1,208	1,169	847	877	11,814	100%

The following distributions of tour types can be defined:

- 11,564 trips (97 per cent) can be directly associated with full tours, shaded in blue in Table 41, of which:
    - 8,038 trips and 1,962 trips form the outward/return leg of a simple tour and complex tour respectively, giving a total of 10,002 trips (84.5 per cent of total trips) equivalent to 5,001 tours for modelling HB travel
    - 1,562 trips (13 per cent of total trips) are NHB trips that can be associated with complex full tours, and models for NHB travel can be developed from these trips
- 79 trips (1 per cent of total trips) form outward half tours
- 76 trips (1 per cent of total trips) form return half tours
- There are only four standalone trips (less than 0.04 per cent of total trips) that cannot be associated with either full or half tours.

Half tours account for just 2 per cent of total trips. *Outward* half tours have been included in the frequency models to ensure that the total volume of travel is modelled correctly, but all half tours have been dropped from the mode-destination choice modelling as the samples are small and the timing information of one of the tour legs is unknown (which means that they cannot be included in the estimations without making assumptions about the missing timing information).

Home-based tour analysis

The remainder of the tables presented in this section include the sample of 5,001 full HB tours that are included in the mode-destination modelling.

Table 42 summarises the numbers of tours by tour purpose.

Table 42. Tour purposes, full tours

Purpose	Cardiff (before)	Cardiff (after)	Caerphilly	Ponty-pridd	Barry	Total	Share
commute	383	374	143	112	154	1,166	23.3%
work-related business	5	2	4	1	1	13	0.3%
education	194	161	47	41	72	515	10.3%
shopping	333	351	98	121	153	1,056	21.1%
personal business	57	48	25	15	24	169	3.4%
serve passenger	192	138	49	37	81	497	9.9%
leisure	528	476	160	175	243	1,582	31.6%
commercial	1	2	0	0	0	3	0.1%
Total	1,693	1,552	526	502	728	5,001	100%

The samples of full tours for commute, education, shopping, other (personal business, leisure and commercial combined) and serve passenger tours are sufficient to allow the transfer of HB mode-destination models. Therefore, the existing PRISM models for these purposes can be directly used to set up the transfer approach and estimate the mode constants.

There are just 13 full work-related business tours, and such a small sample size is not adequate for the transfer of a HB business mode-destination model. *Therefore, it was necessary to rely on other data sources to transfer the PRISM HB business model.*

Next, the main and access modes used for the outward and return tour legs have been analysed. For each trip, up to a maximum of four different modes (method of travel) are recorded in the HI data and a tour leg may comprise more than one trip. To determine the main and access modes for a given tour leg, mode hierarchies[14] have been applied to each of the modes recorded for the trips that comprise the tour leg (see Table 43 and Table 44).

[14] The mode hierarchies are consistent with the PRISM model.

Table 43. Main mode hierarchies

Rank	Main mode
1	train
2	bus / coach
3	school bus
4	car driver
5	motorcycle
6	car passenger
7	taxi
8	cycle
9	walk

Table 44. Access mode hierarchies

Rank	Access mode
1	car driver
2	motorcycle
3	car passenger
4	taxi
5	bus / coach
6	school bus
7	train
8	cycle
9	walk

These mode hierarchies were chosen to maximise the volume of PT tours, as well as to maximise the number of park-and-ride tours where highway modes are used to access PT.

The mode allocated for the outward tour leg has been assumed to be the representative mode for the entire tour. This assumption is consistent with the PRISM model, and to re-validate this assumption in the South East Wales context a cross-tabulation was made of the outward and return tour modes for the sample of 5,001 full tours from the HI data (see Table 45 below).

Table 45. Outward and return tour mode cross-tabulation, full tours only

Outward main mode	Return main mode: train	bus	work/sch. bus	car driver	motorcycle	car passenger	taxi	cycle	walk	other	Total	Symmetry	Mode share
train	59	1	0	0	0	2	2	0	1	0	65	90.8%	1.3%
bus	2	291	0	0	0	22	10	0	14	0	339	85.8%	6.8%
wk/sc. bus	0	1	9	0	0	1	0	0	0	0	11	81.8%	0.2%
car driver	2	4	0	2,154	0	14	1	0	8	1	2,184	98.6%	43.7%
motorcycle	0	0	0	0	7	0	0	0	0	0	7	100%	0.1%
car pass.	5	22	0	12	0	862	9	1	39	0	950	90.7%	19.0%
taxi	2	1	0	0	0	0	12	0	0	0	15	80.0%	0.3%
cycle	0	0	0	2	0	6	0	116	2	0	126	92.1%	2.5%
walk	4	14	0	12	0	42	6	0	1,215	0	1,293	94.0%	25.9%
other	0	0	0	2	0	0	0	0	0	9	11	81.8%	0.2%
Total	74	334	9	2,182	7	949	40	117	1,279	10	5,001	94.7%	100%

The outward and return main modes are the same for 4,734 out of 5,001 tours (94.7 per cent). Furthermore, the numbers of tours off the main diagonal generally tend to balance out, minimising any bias that follows from using the outward mode to define the overall tour mode.

In terms of mode shares:

- Car driver has the highest mode share (43.7 per cent), followed by walk (25.9 per cent) and car passenger (19.0 per cent), respectively.
- There are 65 train tours, which account for 1.3 per cent of total tours.
- There are 339 bus tours (6.8 per cent). The volume of work or school bus tours is relatively low (11 tours) and therefore it was decided that these would be modelled together with bus tours.
- Cycle also has a low mode share (2.5 per cent). However, cycle can reasonable be included as a mode using highway LOS and retaining the ability to model policies aimed at encouraging cycling is a useful feature. Therefore cycle was retained as a mode.
- The mode shares of motorcycle, taxi and 'other' modes are very low (shaded in red in Table 45) at 0.1 per cent, 0.3 per cent and 0.2 per cent respectively, and therefore consistent with the PRISM approach it was decided to drop them from the models.

The main and access modes for the outward tour leg are cross-tabulated in Table 46.

Table 46. Outward main mode and access mode cross-tabulation, full tours only

Outward main mode	Return main mode									Total
	car driver	car ;passenger	taxi	bus	train	cycle	walk	other	none	
train	5	1	0	5	0	3	25	0	26	65
bus	3	8	0	0	2	1	56	0	269	339
work/sch. bus	0	2	0	0	0	0	2	0	7	11
car driver	2	4	1	5	5	0	27	3	2,137	2,184
motorcycle	0	0	0	0	0	0	0	0	7	7
car pass.	0	0	1	2	3	1	31	0	912	950
taxi	0	0	0	0	0	0	2	0	13	15
cycle	0	0	0	0	3	0	4	0	119	126
walk	20	7	2	55	16	3	0	0	1,190	1,293
other	0	0	0	0	0	0	0	0	11	11
Total	30	22	4	67	29	8	147	3	4,691	5,001

Of the 65 train tours, just five (7.7 per cent) have car driver as the access mode and one (1.5 per cent) has car passenger. These sample sizes are far too small to allow separate train access mode and station choice models to be calibrated. Therefore information from other datasets has to be used to allow the PRISM train access mode and station choices models to be transferred to the South East Wales context.

For bus, just three (0.8 per cent) tours use car driver as the access mode, and just eight (2.3 per cent) use car passenger. Therefore, consistent with the PRISM approach, all bus access is assumed to be by walk.

Table 47 shows a tabulation of mode shares by purpose. As discussed above, tours made by taxi, motorcycle and other modes have been dropped from the mode-destination model estimations and so the sample sizes for these modes are presented beneath the sample sizes for the modelled modes.

Table 47. Mode shares by tour purpose tabulation, full tours only

Main mode	Return main mode: work	work-related business	education	shopping	personal business	serve passenger	other	none	Total
train	41	0	4	11	0	0	9	0	65
bus	49	0	65	137	13	9	77	0	350
car driver	727	11	34	463	73	273	601	2	2,184
car pass.	106	1	179	160	49	81	374	0	950
cycle	62	0	14	5	1	3	41	0	126
walk	170	0	215	276	31	131	469	1	1,293
taxi	0	1	4	2	2	0	6	0	15
motorcycle	5	0	0	0	0	0	2	0	7
other	6	0	0	2	0	0	3	0	11
Total	1,166	13	515	1,056	169	497	1,582	3	5,001
Purpose share	23.3%	0.3%	10.3%	21.1%	3.4%	9.9%	31.6%	0.1%	23.3%

Analysis of NHB travel

From Table 41, we observe that 14 per cent of total trips can be associated with NHB travel, of which 13 per cent are associated with a full HB tour. Of these 1,562 NHB trips, 1,350 (86 per cent) are associated with NHB detours and 212 (14 per cent) with PD-based tours.

Table 48 summarises the 1,350 trips associated with NHB detours.

Table 48. NHB detour trips by type

Trip type	Frequency	Per cent
simple outward detour	422	31.3%
simple return detour	446	33.0%
complex outward detour	79	5.9%
complex return detour	116	8.6%
complex detour, dropped trips	287	21.3%
Total	1,350	100.0%

Of the NHB-trips associated with detours, 868 (64.3 per cent) can be directly identified as a simple outward detour or a simple return detour. As discussed in Section 2.1.2, to reduce the complexity of the modelling task for complex NHB detours it is assumed that only one detour is made per tour leg, namely the detour to the identified secondary destination. Thus, while 35.7 per cent of the trips form complex chains of trips, only 14.5 per cent of trips are associated with an outward or a return detour, and the rest are not directly modelled. In total there are 1,350 - 287 = 1,063 detours for modelling.

Table 49 summarises the 212 trips associated with PD-based tours.

Table 49. PD-based tour trips by type

Trip type	Frequency	Per cent
simple outward detour	95	45.0%
simple return detour	95	45.0%
complex outward detour	6	2.8%
complex return detour	6	2.8%
complex detour, dropped trips	10	4.3%
Total	212	100.0%

Of the 212 NHB trips associated with PD-based tours, 90 per cent can be directly identified as a simple outward leg or simple return leg of a PD-based tour. Complex tours account for 10 per cent of the trips, of which 5.6 per cent can be associated with an outward leg or a return leg of a PD-based tour. The rest of the trips (4.3 per cent) are dropped because when modelling complex tours a direct return tour between the PD and the SD is represented.

Representing each possible combination of PD purpose and SD purpose in the NHB detour modelling would be unreasonable, as it would result in a large number of purpose combinations with very small sample sizes. Therefore, the detour modelling was simplified to reflect work-related travel (work and work-related business) and all other purposes. The simplified purposes are consistent with the PRISM definition of NHB travel, which allows the higher VOTs associated with work-related travel to be represented in the models.

Following the PRISM approach, three detour mode-destination models have been developed:

1. Detours made during work-related PD tours to work-related SDs
2. Detours made during work-related PD tours to other purpose SDs
3. Detours made during other purpose PD tours to other purpose SDs.[15]

[15] Note that because of the purpose hierarchies used it is not possible to make a detour from another PD to a work-related SD.

For the detour frequency modelling, the models have been further segmented by whether the traveller makes tours on their outward or return journey, as the detour rates are different by direction. Table 50 shows the classification of the detours into the above three cases.

Table 50. Detours by purpose

	PD purpose	SD purpose					
		Work-related		Other		Total	
Outward detour	Work-related	37	7.4%	102	20.3%	139	27.7%
	Other			362	72.3%	362	72.3%
	Total	37	7.4%	464	92.6%	501	100.0%
Return detour	Work-related	53	9.4%	145	25.8%	198	35.2%
	Other			364	64.8%	364	64.8%
	Total	53	9.4%	509	90.6%	562	100.0%
Total	Work-related	90	8.5%	247	23.2%	337	31.7%
	Other			726	68.3%	726	68.3%
	Total	90	8.5%	973	91.5%	1,063	100.0%

Over two-thirds of the detours (68.3 per cent) are case 3 (other PD to other SD); cases 1 and 2 associated with travel from work-related PDs account for 8.5 per cent and 23.2 per cent of total detours respectively.

Table 51 examines the relationship between the identified mode for the HB tour during which the detour is made, and the detour mode. In many cases we would expect these to be the same but they do not have to be so (for example if different modes are used for different trips on the tour leg on which the detour was made).

Table 51. Outward main mode and detour main mode cross-tabulation

				Det_mode											
				Train	Metro	Bus/Coach /WorkBus/ PRBus	School Bus	Car-Driver	Motorcycle	Car-Passenger	Taxi	Cycle	Walk	Other/none /do not know	Total
Outward detour	out_mode	Train	Count	10	1	1		4		1	0	1	3	0	21
			% within out_mode	47.6%	4.8%	4.8%		19.0%		4.8%	.0%	4.8%	14.3%	.0%	100.0%
		Metro	Count	0	1	0		1		1	0	0	2	0	5
			% within out_mode	.0%	20.0%	.0%		20.0%		20.0%	.0%	.0%	40.0%	.0%	100.0%
		Bus/Coach/Work Bus/PRBus	Count	0	0	90		3		8	1	0	37	0	139
			% within out_mode	.0%	.0%	64.7%		2.2%		5.8%	.7%	.0%	26.6%	.0%	100.0%
		School Bus	Count	0	0	0		0		1	0	0	0	0	1
			% within out_mode	.0%	.0%	.0%		.0%		100.0%	.0%	.0%	.0%	.0%	100.0%
		Car-Driver	Count	0	0	0		577		2	0	0	3	0	582
			% within out_mode	.0%	.0%	.0%		99.1%		.3%	.0%	.0%	.5%	.0%	100.0%
		Car-Passenger	Count	0	0	0		0		104	0	0	8	0	112
			% within out_mode	.0%	.0%	.0%		.0%		92.9%	.0%	.0%	7.1%	.0%	100.0%
		Taxi	Count	0	0	0		0		0	4	0	1	0	5
			% within out_mode	.0%	.0%	.0%		.0%		.0%	80.0%	.0%	20.0%	.0%	100.0%
		Cycle	Count	0	0	0		0		0	0	1	0	0	1
			% within out_mode	.0%	.0%	.0%		.0%		.0%	.0%	100.0%	.0%	.0%	100.0%
		Walk	Count	0	0	0		0		0	0	0	106	0	106
			% within out_mode	.0%	.0%	.0%		.0%		.0%	.0%	.0%	100.0%	.0%	100.0%
		Other/none/do not know	Count	0	0	0		0		0	0	0	0	3	3
			% within out_mode	.0%	.0%	.0%		.0%		.0%	.0%	.0%	.0%	100.0%	100.0%
	Total		Count	10	2	91		585		117	5	2	160	3	975
			% within out_mode	1.0%	.2%	9.3%		60.0%		12.0%	.5%	.2%	16.4%	.3%	100.0%
				Det_mode											
				Train	Metro	Bus/Coach /WorkBus/ PRBus	School Bus	Car-Driver	Motorcycle	Car-Passenger	Taxi	Cycle	Walk	Other/none /do not know	Total
Return detour	out_mode	Train	Count	16	0	2	0	0	0	2	0	0	5	0	25
			% within out_mode	64.0%	.0%	8.0%	.0%	.0%	.0%	8.0%	.0%	.0%	20.0%	.0%	100.0%
		Metro	Count	0	6	1	0	0	0	0	0	0	0	0	7
			% within out_mode	.0%	85.7%	14.3%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	100.0%
		Bus/Coach/Work Bus/PRBus	Count	5	0	126	1	1	0	15	0	0	53	2	203
			% within out_mode	2.5%	.0%	62.1%	.5%	.5%	.0%	7.4%	.0%	.0%	26.1%	1.0%	100.0%
		School Bus	Count	0	0	0	1	0	0	1	0	0	0	0	2
			% within out_mode	.0%	.0%	.0%	50.0%	.0%	.0%	50.0%	.0%	.0%	.0%	.0%	100.0%
		Car-Driver	Count	4	0	0	0	650	0	5	2	0	21	3	685
			% within out_mode	.6%	.0%	.0%	.0%	94.9%	.0%	.7%	.3%	.0%	3.1%	.4%	100.0%
		Motorcycle	Count	0	0	0	0	0	3	0	0	0	0	0	3
			% within out_mode	.0%	.0%	.0%	.0%	.0%	100.0%	.0%	.0%	.0%	.0%	.0%	100.0%
		Car-Passenger	Count	0	1	9	1	4	0	135	1	1	23	1	176
			% within out_mode	.0%	.6%	5.1%	.6%	2.3%	.0%	76.7%	.6%	.6%	13.1%	.6%	100.0%
		Taxi	Count	0	0	0	0	0	0	0	1	0	1	0	2
			% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	50.0%	.0%	50.0%	.0%	100.0%
		Cycle	Count	0	0	0	0	0	0	0	0	6	0	0	6
			% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	100.0%	.0%	.0%	100.0%
		Walk	Count	0	0	13	2	3	0	19	0	0	126	0	163
			% within out_mode	.0%	.0%	8.0%	1.2%	1.8%	.0%	11.7%	.0%	.0%	77.3%	.0%	100.0%
		Other/none/do not know	Count	0	0	0	0	0	0	0	0	0	0	9	9
			% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	100.0%	100.0%
	Total		Count	25	7	151	5	658	3	177	4	7	229	15	1281
			% within out_mode	2.0%	.5%	11.8%	.4%	51.4%	.2%	13.8%	.3%	.5%	17.9%	1.2%	100.0%

Of the 975 outward detours, the outward main mode and detour mode are identical for 859 (91.8 per cent) records. Walk, car driver and car passenger show stronger correlations between outward main and detour modes compared to other modes and together with bus account for 97 per cent of the outward detours. There are no outward detour records where either school bus or motorcycle are the detour mode.

Of the 1,281 return detours the outward main mode and detour mode are identical for 1,079 (84.2 per cent) records. The closest association is seen for car driver (94.9 per cent), which is also the dominant mode with a share of 51.4 per cent. Car driver, car passenger, walk and bus modes account for 95 per cent of the return detours.

Given the strong relationship between the detour mode and the main tour mode, consistent with the PRISM approach the detour mode has been used to for assigning the mode choice in the detour models and then constants are identified for the corresponding outward main mode to account for the strong positive correlations between the two modes. There are three and 15 outward and return detours respectively for which the detour mode is unknown and these have been dropped from the modelling.

Table 52 shows the cross-tabulation between HB-tour purpose and PD-based tour purpose. The majority of PD-based tours are for other purposes. Employer's business and not usual workplace purposes together account for 24.7 per cent of all the PD-based tours.

Given the volumes of PD-based tours available for estimation, the PD and SD purposes are simplified to reflect the same cases identified for the detour modelling presented earlier in this section. Table 52 shows the classification of PD-based tours in the three cases: cases 1, 2 and 3 account for 28.2 per cent, 46.3 per cent and 25.5 per cent of the PD-based tours respectively.

Table 52. PD-based tours by simplified purpose

	PD purpose	SD purpose					
		Work-related		Other		Total	
Outward detour	Work-related	53	28.2%	87	46.3%	140	74.5%
	Other			48	25.5%	48	25.5%
	Total	53	28.2%	135	71.8%	188	100.0%

In contrast to the detours summarised in Table 50, the majority of PD-based tours are associated with work-related PDs.

Table 53 below shows a cross-tabulation between the outward main modes and the PD-based tour mode. Cells on the main diagonal where the outward and the PD-based mode are identical are highlighted in grey.

Table 53. Mode shares for work-based tours

			SD Mode							
			Train	Metro	Bus/Coach /WorkBus/ PRBus	Car-Driver	Car-Passenger	Walk	Other/none /do not know	Total
PD_Mode	Train	Count	0	0	0	0	0	5	0	5
		% within out_mode	.0%	.0%	.0%	.0%	.0%	100.0%	.0%	100.0%
	Metro	Count	0	0	0	0	0	2	0	2
		% within out_mode	.0%	.0%	.0%	.0%	.0%	100.0%	.0%	100.0%
	Bus/Coach /WorkBus/ PRBus	Count	1	8	0	0	2	25	0	36
		% within out_mode	2.8%	22.2%	.0%	.0%	5.6%	69.4%	.0%	100.0%
	Car-Driver	Count	0	0	0	66	6	30	12	114
		% within out_mode	.0%	.0%	.0%	57.9%	5.3%	26.3%	10.5%	100.0%
	Car-Passenger	Count	0	0	0	0	7	5	1	13
		% within out_mode	.0%	.0%	.0%	.0%	53.8%	38.5%	7.7%	100.0%
	Cycle	Count	0	0	0	0	0	0	1	1
		% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	100.0%	100.0%
	Walk	Count	0	1	1	1	2	11	0	16
		% within out_mode	.0%	6.3%	6.3%	6.3%	12.5%	68.8%	.0%	100.0%
	Other/none /do not know	Count	0	0	0	0	0	0	1	1
		% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	100.0%	100.0%
Total		Count	1	9	1	67	17	78	15	188
		% within out_mode	.5%	4.8%	.5%	35.6%	9.0%	41.5%	8.0%	100.0%

For 85 of 188 tours (45.2 per cent), the outward main mode and the PD-based tour mode are identical, a much lower level of association than was observed for detours made in the course of HB tours. Car driver and walk modes account for 70 per cent (136) of PD-based tours. Consistent with the PRISM approach, the PD-based tour mode has been used to define the observed mode choice in the models and constants have been estimated to take account of the positive correlations with the corresponding HB tour mode. It is noted that 15 tours (8 per cent) where the mode is unknown have been excluded from the modelling.

Appendix B: Ward coding in PTP survey

This table presents a summary of the ward numbers in each of the four PTP areas.

Table 54. Cardiff ward coding

Number	Name
1	Adamsdown
2	Butetown
3	Caerau
4	Canton
5	Cathays
6	Cornerswell
7	Cyncoed
8	Ely
9	Fairwater
10	Gabalfa
11	Grangetown
12	Heath
13	Lisvane
14	Llandaff
15	Llandaff North
16	Llandough
17	Llanishen
18	Llanrumney
19	Pentwyn
20	Penylan
21	Plasnewydd

Number	Name
22	Plymouth
23	Pontprennau/Old St. Mellons
24	Radyr
25	Rhiwbina
26	Riverside
27	Rumney
28	Splott
29	St. Augustine's
30	Stanwell
31	Sully
32	Trowbridge
33	Whitchurch and Tongwynlais

Table 55. Caerphilly ward coding

Number	Name
1	Aber Valley
2	Bedwas, Trethomas and Machen
3	Llanbradach
4	Morgan Jones
5	Penyrheol
6	St. James
7	St. Martins

Table 56. Pontypridd ward coding

Number	Name
1	Cilfynydd
2	Glyncoch
3	Graig
4	Hawthorn
5	Pontypridd Town
6	Rhondda
7	Rhydfelen Central/Ilan
8	Taffs Well
9	Trallwng
10	Treforest

Table 57. Barry ward coding

Number	Name
1	Baruc
2	Buttrills
3	Cadoc
4	Castleland
5	Court
6	Dyfan
7	Gibbonsdown
8	Illtyd

Appendix C: Public transport level of service data

WebTAG states:

> In principle, if in-vehicle crowding is, or is expected to be, so severe that demand for the mode concerned is, or would be, constrained, some means of representing the costs of the crowding for use in the demand model would be required.

Crowding in the public transport model has been included based on the in-vehicle time penalty approach outlined in the Passenger Demand Forecasting Handbook (PDFH) and applied to rail travel only.

Adopting a schedule-based approach allows capacity restraint and discomfort due to crowding to be modelled explicitly. The VISUM software allows a crowding impedance function to be defined on rail services, which is considered during assignment based on vehicle capacities.

Seating capacity and standing area for different types of rolling stock were taken predominantly from PDFH. Rolling stock information was based upon information provided by rail operators, although some assumptions were required to assign rolling stop types to some services.

The crowding penalty curve was based upon the standard curve in PDFH, with an adaptation to make it suitable for use with the software. The software does not allow for crowding penalties to be extracted without an influence on route choice but parameters can be utilised that will minimise this effect whilst retaining all the information to feed the demand model. It is possible to turn the crowding function off to improve model run times. The model has been calibrated will the full effect of crowding included as a component of route choice.

Generalised cost formulation

The VISUM assignment model will use a timetable- (or schedule-) based assignment process, and this would allow fares to be included in the assignment procedure. The Generalised Journey Time (GJT in minutes) of the assignment algorithm that informs the path search mechanism for the most attractive path for each origin-destination pair would take the following form:

$$GJT = A*(IVT) + B*(AT) + C*(ET) + D*(WT) + E*(OWT) + F*(TWT) + G*TF + CP$$

where:

- IVT = in-vehicle time
- AT and ET = access and egress time
- WT = walking time

- OWT and TWT = origin and transfer waiting time
- TF = Transfer penalty (minutes) per number of transfers
- CP = Crowding Penalty (rail only)
- A, B, C, D, E, F and G are weights associated with each element above.

In-vehicle time will be based on the information within the model obtained from timetables. WebTAG provides guidance on the weights to be applied to each of the attributes listed above. The different elements of generalised cost will also be skimmed and outputted in a suitable format for the demand model. The various components of generalised cost are weighted to reflect the perceived time spent at each step of the public transport journey as set out in Table 58; values are consistent with guidance in WebTAG Unit M3.2.

Table 58. Generalised cost weights

Attribute	
Access Time	1.75
Egress Time	1.75
Walk Time	2.00
Origin Wait Time	2
Transfer Wait Time	2
Transfer Penalty	10mins
Walk Speed	5kph
IVT Bus	1.0
IVT Rail	0.9
Boarding Penalty Factor	1

Source: Mott MacDonald

Assignment method

A key issue for the PT assignment model is whether trips are allocated between public transport modes at the mode choice stage or at the assignment stage. The pros and cons of each approach were assessed and it was agreed with WG that the PT sub-mode choice will be modelled within the demand model.

As a corollary there will also be no need to split between concessionary and non-concessionary passes in the assignment as there is no need to represent fares within the assignment.

A key decision to be made was whether the assignment is frequency or schedule-based. Guidance on this is available in WebTAG Unit M3.2, Table 1. Based on this table, the adopted assignment procedure is schedule-based and allows crowding to be modelled.

The public transport model uses a stochastic user equilibrium (SUE) as this assignment method recognises individual variations in generalised cost perception. This should lead to trips being split between more paths than in the alternative (deterministic) case, which is more realistic. The route choice will be based on a power function (Kirchoff). In a Kirchoff assignment, passengers are distributed over paths according to the power of the ratio of the costs of alternative paths.

Appendix D: West Midlands model parameters

This Appendix documents the PRISM West Midlands mode-destination model parameters that were transferred to the South East Wales context.

Commute

Parameter	Description	Model v134 value	Model v134 t-ratio
Cost parameters:			
GcostNA	Gamma cost parameter, income not stated	-0.0068	-18.9
Gcost123	Gamma cost parameter, HH inc < £25k p.a.	-0.0080	-20.3
Gcost45	Gamma cost parameter, HH inc £25-35k p.a.	-0.0070	-15.7
Gcost67	Gamma cost parameter, HH inc £35-50k p.a.	-0.0067	-14.9
Gcost811	Gamma cost parameter, HH inc > £50k p.a.	-0.0055	-11.5
Level of service parameters:			
CarTime	Car in-vehicle time	-0.0331	-22.6
CarPDist	Car passenger distance	-0.0179	-6.0
PTGenTme	PT generalised time (both in and out vehicle)	-0.0211	-19.0
Transfers	Public transport transfers	-0.1357	-3.2
CycleDist	Cycle distance	-0.1658	-9.6
WalkDist	Walk distance	-0.5028	-28.3
Socio-economic parameters:			
FreeCarUse	Free car use term on car driver	1.0892	7.0
OneCarComp	Car competition for one HH car, car driver	-0.7009	-4.7
PassOpt	Passenger opportunity term, car passenger	0.9433	5.3
FreeUseCrP	Free car use term, car passenger	-0.5604	-2.7
CarPMale	Male car passenger constant	-0.3040	-2.2
TrIncGt50k	Train high income term (HH inc > £50k p.a.)	0.4359	1.5
Trn_0cars	Zero cars term on train	-0.9334	-2.9
Bus_0cars	Zero cars term on bus	0.2715	1.8
BusMale	Male bus constant	-0.5302	-4.1
Bus_17_24	Constant for persons aged 17-24 on bus	0.5629	3.7
CycleMale	Male cycle constant	1.8654	4.8
WalkMale	Male walk constant	-0.5276	-3.9
PTworkdist	Part-time worker distance	-0.0415	-10.1
Mode constants:			
CarP	Car passenger (relative to car driver)	0.3678	1.3
Train	Train (relative to car driver)	1.6885	7.1
Metro	Metro (relative to car driver)	0.8991	2.9
Bus	Bus (relative to car driver)	3.5128	15.7
Cycle	Cycle (relative to car driver)	-1.8903	-4.2
Walk	Walk (relative to car driver)	3.8187	16.3
Time period constants:			
TP_11	Out AM peak, return AM peak	-2.0730	-4.8
TP_12	Out AM peak, return inter-peak	1.6166	10.4
TP_13	Out AM peak, return PM peak	3.4217	23.8
TP_14	Out AM peak, return off-peak	0.9275	5.5
TP_22	Out inter-peak, return inter-peak	-0.1054	-0.5
TP_23	Out inter-peak, return PM peak	1.0569	6.4
TP_24	Out inter-peak, return off-peak	0.6729	3.9
TP_33	Out PM peak, return PM peak	-1.5279	-4.4
TP_34	Out PM peak, return off-peak	0.1283	0.7
TP_41	Out off-peak, return AM peak	-2.1087	-4.9
TP_42	Out off-peak, return inter-peak	1.0784	6.6
TP_43	Out off-peak, return PM peak	1.5351	9.8
TP_44	Out off-peak, return off-peak (base combination)	0.0000	n/a
Attraction variable:			
TotEmp	Total employment attraction variable	1.0000	n/a
Structural parameters:			
TR_M_TP	Relative sensitivity of modes and time periods	1.0000	n/a
TR_TP_D	Relative sensitivity of time periods and destinations	1.0000	n/a

Home–business

Parameter	Description	Model v60 Value	Model v60 t-ratio
Level of service parameters:			
GenTime	Generalised time	-0.023	-26.6
CarPDist	Car passenger distance	-0.013	-6.1
CycleDist	Cycle distance	-0.107	-1.0
WalkDist	Walk distance	-0.736	-5.0
Socio-economic parameters:			
CarComp	Car competition in household	-3.214	-2.8
PTworkdist	Part-time worker distance	-0.017	-2.8
Mode constants:			
CarP	Car passenger (relative to car driver)	-0.843	-1.2
Train	Train (relative to car driver)	-0.392	-0.3
Metro	Metro (relative to car driver)	-3.601	-1.3
Bus	Bus (relative to car driver)	2.005	2.8
Cycle	Cycle (relative to car driver)	-5.451	-1.7
Walk	Walk (relative to car driver)	3.831	3.4
Time period constants:			
TP_11	Out AM peak, return AM peak	-3.004	-1.9
TP_12	Out AM peak, return inter-peak	1.740	2.3
TP_13	Out AM peak, return PM peak	4.262	3.1
TP_14	Out AM peak, return off-peak	-0.285	-0.4
TP_22	Out inter-peak, return inter-peak	1.437	2.0
TP_23	Out inter-peak, return PM peak	2.551	2.7
TP_24	Out inter-peak, return off-peak	0.261	0.4
TP_33	Out PM peak, return PM peak	-1.485	-1.5
TP_34	Out PM peak, return off-peak	0.488	0.7
TP_41	Out off-peak, return AM peak (never chosen)	0.000	n/a
TP_42	Out off-peak, return inter-peak	-0.488	-0.6
TP_43	Out off-peak, return PM peak	1.245	1.8
TP_44	Out off-peak, return off-peak (base combination)	0.000	n/a
Destination constants:			
IntraDest	Intrazonal destinations	2.310	7.8
WalkIZ	Walk intrazonal constant	-2.181	-3.0
Attraction variable:			
TotEmp	Total employment attraction variable	1.000	n/a
Structural parameters:			
TR_M_TP	Relative sensitivity of modes and time periods	1.000	n/a
TR_TP_D	Relative sensitivity of time periods and destinations	0.590	2.3

Home–primary education

Parameter	Description	Model v27 value	t-ratio
Cost parameters:			
LogCost		-0.619	-6.5
Level of service parameters:			
CarTime	Car time	-0.051	-2.8
PTGenTime	Public transport generalised time	-0.030	-11.5
CarPDist	Car passenger distance	-0.244	-7.1
CycleDist	Cycle distance	-0.502	-3.8
WalkDist	Walk distance	-0.614	-27.5
Socio-economic parameters:			
PassOpt	Passenger opportunity	2.907	8.3
CrP2PlCars	Two-plus cars term on car passenger	0.673	4.9
BsNocars	Zero cars constant on bus	0.632	2.4
Mode constants:			
TrainMetro	Train and metro (relative to car passenger)	0.313	0.3
Bus	Bus (relative to car passenger)	3.886	5.7
Cycle	Cycle (relative to car passenger)	-0.608	-0.8
Walk	Walk (relative to car passenger)	4.346	12.3
Destination constants:			
IntraDest	Intrazonal destinations	0.521	5.6
Attraction variable:			
PEnrols	Primary enrolments attraction variable	1.000	n/a
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.000	n/a

Home–secondary education

Parameter	Description	Model v30 value	Model v30 t-ratio
Cost parameters:			
LogCost	Log of cost	-0.572	-6.4
Level of service parameters:			
CarTime	Car time	-0.130	-18.9
CycleDist	Cycle distance	-0.404	-4.7
WalkDist	Walk distance	-0.559	-27.2
Socio-economic parameters:			
PassOpt	Passenger opportunity	2.460	4.2
CarPOneCar	One car constant on car passenger	-0.619	-2.6
CyMale	Male constant on cycle	2.721	2.1
Mode constants:			
TrainMetro	Train and metro (relative to car passenger)	1.373	1.7
Bus	Bus (relative to car passenger)	5.634	6.5
Cycle	Cycle (relative to car passenger)	-2.227	-1.5
Walk	Walk (relative to car passenger)	4.939	7.8
Attraction variable:			
SecEnrol	Secondary enrolments attraction variable	1.000	n/a
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	0.823	1.7

Home–tertiary education

Parameter	Description	Model v64 value	Model v64 t-ratio
Cost parameters:			
GCost	Gamma cost parameter	-0.0032	-7.3
Level of service parameters:			
CarTime	Car time	-0.0312	-7.8
CarPDist	Car passenger distance	-0.0726	-4.6
PTGenTime	Public transport generalised time	-0.0170	-15.8
CycleDist	Cycle distance	-0.2109	-4.1
WalkDist	Walk distance	-0.4559	-14.0
Socio-economic parameters:			
CarComp	Competition for cars in HH	-1.9526	-5.4
PassOpt	Passenger opportunity term	1.3536	3.0
BusCarsge2	Two-plus HH cars term on bus	-0.8596	-3.5
WkCarsge2	Two-plus HH cars term on walk	-1.3105	-3.8
WkRet	Retired persons term on walk	3.8579	3.1
CyHSizEq1	Single person HH term on cycle	3.1980	4.1
Mode constants:			
CarP	Car passenger (relative to car driver)	-3.7746	-6.7
Train	Train (relative to car driver)	-2.5173	-6.3
Metro	Metro (relative to car driver)	-3.7571	-6.0
Bus	Bus (relative to car driver)	-0.3924	-1.1
Cycle	Cycle (relative to car driver)	-4.3414	-6.4
Walk	Walk (relative to car driver)	0.0012	0.0
Size variables:			
SizeMult	Base size term	1.0000	n/a
TotEmpFTS	Total employment term, FT students	-3.3223	-23.1
TotEmpOth	Total employment term, other status groups	-2.4097	-9.7
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.0000	n/a

Home–shopping

Parameter	Description	Model v104 value	Model v104 t-ratio
Cost parameters:			
GCostNA	Gamma cost parameter, income not stated	-0.0176	-9.0
GCost1t5	Gamma cost parameter, HH inc < £35k p.a.	-0.0204	-10.5
GCost611	Gamma cost parameter, HH inc > £35k p.a.	-0.0159	-6.6
Level of service parameters:			
CarTime	Car in-vehicle time	-0.0715	-14.4
PTGenTme	PT generalised time (both in and out vehicle)	-0.0475	-22.3
Transfers	Public transport transfers	0.1188	2.0
CycleDist	Cycle distance	-0.2065	-2.3
WalkDist	Walk distance	-0.6241	-21.7
Socio-economic parameters:			
OneCarFree	Free car use term on car driver, 1 car in HH	2.0558	3.2
2PlCarFree	Free car use term on car driver, 2+ cars in HH	2.5843	4.0
PassOp2Hh	Passenger opportunity term, car pass., 2 person HH	6.5038	6.1
PassOp3PHh	Passenger opportunity term, car pass., 3+ person HH	5.3666	5.7
CarPFTstu	Full-time student car passenger constant	2.4650	2.6
CarPRetir	Retired persons car passenger constant	1.8022	3.0
CarPMale	Male car passenger constant	-2.1698	-3.6
BusMale	Male term on bus	-1.3147	-2.6
BusNoCar	Zero car constant on bus	2.4358	4.4
Mode constants:			
CarP	Car passenger (relative to car driver)	-2.2598	-2.6
Train	Train (relative to car driver)	-4.4756	-4.0
Metro	Metro (relative to car driver)	-7.7262	-4.0
Bus	Bus (relative to car driver)	4.6275	5.6
Cycle	Cycle (relative to car driver)	-14.1714	-5.5
Walk	Walk (relative to car driver)	4.1818	5.4
Time period constants:			
TP_11	Out AM peak, return AM peak	-8.4058	-4.1
TP_12	Out AM peak, return inter-peak	0.1718	0.3
TP_13	Out AM peak, return PM peak	-10.7072	-3.8
TP_14	Out AM peak, return off-peak	0.0000	n/a
TP_22	Out inter-peak, return inter-peak	7.0457	7.0
TP_23	Out inter-peak, return PM peak	0.9816	1.5
TP_24	Out inter-peak, return off-peak	0.0000	n/a
TP_33	Out PM peak, return PM peak	1.4733	2.3
TP_34	Out PM peak, return off-peak	-1.1314	-1.5
TP_41	Out off-peak, return AM peak	0.0000	n/a
TP_42	Out off-peak, return inter-peak	-13.1497	-3.5
TP_43	Out off-peak, return PM peak	0.0000	n/a
TP_44	Out off-peak, return off-peak (base combination)	0.0000	n/a
Destination constants:			
WalkIZ	Walk intrazonal constant	0.8480	5.3
Attraction variable:			
RetailEmp	Retail employment attraction variable	1.0000	n/a
Structural parameters:			
TR_M_TP	Relative sensitivity of modes and time periods	1.0000	n/a
TR_TP_D	Relative sensitivity of time periods and destinations	0.2944	19.5

Home–serve passenger

Parameter	Description	Model v47 value	t-ratio
Cost parameters:			
GCost	Gamma cost parameter	-0.0159	-9.9
Level of service parameters:			
CarTime	Car time	-0.0691	-10.5
BsGTime	Generalised bus time	-0.0275	-8.2
WalkDist	Walk distance	-0.5597	-25.8
Socio-economic parameters:			
OneCarComp	Competition for car, 1 car in HH	-1.7968	-4.6
PassOpt	Passenger opportunity term	1.5458	1.9
BusNoCar	No car constant on bus	3.2929	4.1
BusFemale	Female constant on bus	3.0977	3.1
HHchild	Constant on walk for HHs with children	5.1092	4.7
Mode constants:			
CarP	Car passenger (relative to car driver)	-6.7068	-6.2
Bus	Bus (relative to car driver)	-3.6604	-2.9
Walk	Walk (relative to car driver)	-1.1432	-1.3
Time period constants for car driver:			
TP_11	Out AM peak, return AM peak	3.1999	5.9
TP_12	Out AM peak, return inter-peak	-3.4147	-4.0
TP_13	Out AM peak, return PM peak	-6.0532	-4.0
TP_14	Out AM peak, return off-peak	0.0000	n/a
TP_22	Out inter-peak, return inter-peak	2.1743	4.9
TP_23	Out inter-peak, return PM peak	1.3164	3.4
TP_24	Out inter-peak, return off-peak	-6.1242	-4.0
TP_33	Out PM peak, return PM peak	1.6785	4.2
TP_34	Out PM peak, return off-peak	-2.2653	-3.5
TP_41	Out off-peak, return AM peak	-6.9505	-3.9
TP_42	Out off-peak, return inter-peak (never chosen)	0.0000	n/a
TP_43	Out off-peak, return PM peak (never chosen)	0.0000	n/a
TP_44	Out off-peak, return off-peak (base combin.)	0.0000	n/a
Destination constants:			
CarPIZ	Car passenger intrazonal constant	2.4465	5.7
WalkIZ	Walk intrazonal constant	0.8813	8.0
Attraction variable:			
L_S_M	Log-size multiplier	1.0000	n/a
Size_Pop	Population size parameter	0.2004	-5.7
Size_Prim	Primary enrolments size parameter	25.3402	22.4
Size_Sec	Secondary enrolments size parameter	5.7838	8.2
Structural parameters:			
TR_M_TP	Relative sensitivity of modes and time periods	1.0000	n/a
TR_TP_D	Relative sensitivity of time periods and dest.s	0.4836	7.4

Home–other travel

Parameter	Description	Model v126 value	Model v126 t-ratio
Cost parameters:			
GCostNA	Gamma cost parameter, income not stated	-0.0085	-8.0
Gcost1t5	Gamma cost parameter, HH inc < £35k p.a.	-0.0097	-8.4
Gcost67	Gamma cost parameter, HH inc £35-50k p.a.	-0.0085	-5.9
Gcost811	Gamma cost parameter, HH inc > £50k p.a.	-0.0074	-5.8
Level of service parameters:			
CarTime	Car in-vehicle time	-0.0497	-16.0
PTGenTme	PT generalised time (both in and out vehicle)	-0.0269	-15.6
Transfers	Public transport transfers	-0.2076	-3.5
CycleDist	Cycle distance	-0.2483	-7.7
WalkDist	Walk distance	-0.4870	-23.8
Socio-economic parameters:			
LAFdist	Looking after family distance term	-0.0310	-3.5
FreeCarUse	Free car use term on car driver	1.5911	4.0
PassOp2Hh	Passenger opportunity term, car pass., 2 pers HH	4.2651	5.5
PassOp3Hh	Passenger opportunity term, car pass., 3+ pers HH	3.0610	4.9
CarP5t11	Car passenger term, aged 5-11	3.8793	3.8
CarPRet	Retired constant on car passenger	0.5959	1.5
CarPMale	Male constant on car passenger	-1.6833	-4.2
BusUemp	Unemployed persons constant on bus	1.3066	2.5
BusFemale	Female constant on bus	0.9657	2.4
BusNoCar	No car constant on bus	1.7124	3.6
BikeMale	Male constant on cycle	3.5591	2.6
Mode constants:			
CarP	Car passenger (relative to car driver)	-0.8738	-1.7
Train	Train (relative to car driver)	-4.5199	-4.7
Metro	Metro (relative to car driver)	-9.5536	-4.7
Bus	Bus (relative to car driver)	-0.0009	0.0
Cycle	Cycle (relative to car driver)	-9.8187	-5.1
Walk	Walk (relative to car driver)	1.8434	4.6
Time period constants:			
TP_11	Out AM peak, return AM peak	-6.0811	-5.4
TP_12	Out AM peak, return inter-peak	-3.2687	-5.0
TP_13	Out AM peak, return PM peak	-6.3207	-5.4
TP_14	Out AM peak, return off-peak	-10.4200	-5.1
TP_22	Out inter-peak, return inter-peak	1.1938	3.6
TP_23	Out inter-peak, return PM peak	-0.4176	-1.3
TP_24	Out inter-peak, return off-peak	-7.2502	-5.5
TP_33	Out PM peak, return PM peak	-1.7980	-3.9
TP_34	Out PM peak, return off-peak	-0.0236	-0.1
TP_41	Out off-peak, return AM peak	-10.4396	-5.1
TP_42	Out off-peak, return inter-peak	-9.9237	-5.2
TP_43	Out off-peak, return PM peak	-15.0949	-4.1
TP_44	Out off-peak, return off-peak (base combination)	0.0000	n/a
Destination constants:			
IntraDest	Intrazonal destination term	0.1907	1.4
WalkIZ	Walk intrazonal destination term	0.7838	4.1
Attraction variable:			
L_S_M	Log-size multiplier	1.0000	n/a
Size_Ser	Size term on service employment	4.1333	15.4
Size_Ret	Size term on retail employment	5.9845	9.3
Structural parameters:			
TR_M_TP	Relative sensitivity of modes and time periods	1.0000	n/a
TR_TP_D	Relative sensitivity of time periods and destinations	0.3427	13.0

PD-based work–work tours

Parameter	Description	Model v19 value	Model v19 t-ratio
Cost parameter:			
LogCost	Log of cost	-0.756	-3.9
Level of service parameters:			
GenTime	Generalised time	-0.020	-3.7
CarPDist	Car passenger distance	-0.067	-1.5
WalkDist	Walk distance	-0.227	-1.2
Mode constants:			
CarP	Car passenger (relative to car driver)	-4.839	-3.6
Train	Train (relative to car driver)	-3.129	-2.9
Bus	Bus (relative to car driver)	-3.054	-2.0
Walk	Walk (relative to car driver)	-4.653	-2.3
Attraction variable:			
TotEmp	Total employment attraction variable	1.000	n/a
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.000	n/a

PD-based work–other tours

Parameter	Description	Model v24 value	Model v24 t-ratio
Cost parameter:			
LogCost	Log of cost	-0.546	-2.1
Level of service parameters:			
CarTime	Car in-vehicle time	-0.065	-4.0
PTGenTime	PT generalised time	-0.026	-2.1
CarPDist	Car passenger distance	-0.112	-1.5
WalkDist	Walk distance	-0.546	-9.4
Mode constants:			
CarP	Car passenger (relative to car driver)	-3.086	-2.3
Bus	Bus (relative to car driver)	-2.778	-2.0
Walk	Walk (relative to car driver)	0.804	0.8
Attraction variables:			
SizeMult	Log-size multiplier	1.000	n/a
Size_Ret	Size term on retail employment	38.046	8.8
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.000	n/a

PD-based other–other tours

Parameter	Description	Model v33 value	Model v33 t-ratio
Level of service parameters:			
GTime	Generalised time (including monetary costs)	-0.028	-5.2
CarPDist	Car passenger distance	-0.284	-3.1
WalkDist	Walk distance	-0.558	-5.8
Home-based tour mode constants:			
HBMCarP	Home-based & NHB mode car passenger	4.021	3.1
Mode constants:			
CarP	Car passenger (relative to car driver)	-0.234	-0.2
Bus	Bus (relative to car driver)	-0.035	-0.1
Walk	Walk (relative to car driver)	2.239	3.0
Attraction variables:			
SizeMult	Log-size multiplier	1.000	n/a
Size_Ser	Size term on retail employment	5.907	2.3
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.000	n/a

Work–work detours

Parameter	Description	Model v37 Value	Model v37 t-ratio
Cost parameters:			
Gcost	Gamma cost parameter	-0.0022	-2.4
Level of service parameters:			
GenTime	Generalised time	-0.0645	-6.8
CarPDist	Car passenger distance	-0.0387	-1.0
WalkDist	Walk distance	-1.0831	-3.0
Home-based tour mode constants:			
HBMCarD	Both home-based and NHB mode car driver	3.0105	2.0
HBMBus	Both home-based and NHB mode car driver	2.5166	2.5
Mode constants:			
CarP	Car passenger (relative to car driver)	-1.6116	-1.0
Train	Train (relative to car driver)	-1.2952	-0.8
Bus	Bus (relative to car driver)	1.1321	0.7
Walk	Walk (relative to car driver)	2.2637	1.4
Destination constants:			
CarPIZ	Car passenger intrazonal destinations	2.9026	2.3
Attraction variable:			
TotEmp	Total employment attraction variable	1.0000	n/a
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.0000	n/a

Work–other detours

Parameter	Description	Model v44 value	Model v44 t-ratio
Cost parameters:			
Gcost	Gamma cost parameter	-0.0060	-5.9
Level of service parameters:			
CarTime	Car in-vehicle time	-0.0934	-13.2
PTGenTime	PT generalised time	-0.0432	-8.8
CarPDist	Car passenger distance	-0.0263	-1.5
WalkDist	Walk distance	-0.5783	-13.7
Socio-economic parameters:			
PTworkdist	Part-time worker distance	-0.0343	-3.2
CarComp	Car competition	-1.1459	-2.2
Home-based tour mode constants:			
HBMCarD	Both home-based and NHB mode car driver	6.4969	10.7
HBMCarP	Both home-based and NHB mode car passenger	3.6211	7.0
HBMTrn	Both home-based and NHB mode train	3.9614	5.1
HBMBus	Both home-based and NHB mode car driver	2.8763	5.1
Mode constants:			
CarP	Car passenger (relative to car driver)	-0.0070	0.0
Train	Train (relative to car driver)	-1.2201	-1.4
Metro	Metro (relative to car driver)	0.3503	0.3
Bus	Bus (relative to car driver)	0.3328	0.4
Walk	Walk (relative to car driver)	3.3034	5.6
Attraction variable:			
SizeMult	Log-size multiplier	1.0000	n/a
Size_Ret	Retail employment size term	5.2056	9.7
Size_Ser	Service employment size term	0.6147	-2.5
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.0000	n/a

Other–other detours

Parameter	Description	Model v45 value	t-ratio
Cost parameters:			
GCost1t7	Gamma cost parameter, HH inc <£50k p.a.	-0.027	-7.8
GCost811	Gamma cost parameter, HH inc £50k+ p.a.	-0.020	-3.5
GCostNA	Gamma cost parameter, income not stated	-0.019	-5.6
Level of service parameters:			
CarTime	Car in-vehicle time	-0.094	-6.9
PTGenTime	PT generalised time	-0.060	-10.7
Transfers	PT transfers	-0.183	-0.9
CarPDist	Car passenger distance	-0.075	-4.6
CycleDist	Cycle distance	-0.344	-3.3
WalkDist	Walk distance	-0.749	-19.1
Socio-economic parameters:			
PassOpt	Passenger opportunity term, car passenger	3.174	2.2
Home-based tour mode constants:			
HBMCarD	Both home-based and NHB mode car driver	19.713	3.9
HBMCarP	Both home-based and NHB mode car passenger	11.611	3.8
HBMTrn	Both home-based and NHB mode train	16.595	3.0
HBMBus	Both home-based and NHB mode bus	8.828	3.5
HBMWLK	Both home-based and NHB mode walk	5.558	3.2
Mode constants:			
CarP	Car passenger (relative to car driver)	-3.322	-1.8
Train	Train (relative to car driver)	-10.683	-2.5
Metro	Metro (relative to car driver)	-2.464	-0.9
Bus	Bus (relative to car driver)	0.679	0.4
Cycle	Cycle (relative to car driver)	-8.580	-3.1
Walk	Walk (relative to car driver)	4.140	2.4
Destination constants			
IntraDest	Intrazonal destinations	0.635	4.5
CarDIZ	Intrazonal destinations, car driver	-1.112	-4.2
Attraction variable:			
SizeMult	Log-size multiplier	1.000	n/a
Size_Ret	Retail employment size term	8.430	16.2
Size_Ser	Service employment size term	0.863	-0.9
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	0.254	12.1

Appendix E: Transfer model parameters

This Appendix presents the full set of parameter results from the model transfers for the set of models that have been taken forward for implementation. Where the transfer scale has not been fixed to one the t-ratio states the significance of the scale estimate relative to a value of one. For all other parameter estimates the t-ratio states the significance of the parameter estimate relative to a value of zero.

Commute

Parameter	Description	Model v29	
		value	t-ratio
Transfer scale			
Scale	Transfer scale	0.7184	12.2
Mode constants:			
CarP	Car passenger (relative to car driver)	0.3556	1.7
Bus	Bus (relative to car driver)	1.4070	6.0
Train	Train (relative to car driver)	1.0487	4.4
Bike	Cycle (relative to car driver)	-0.5465	-2.4
Walk	Walk (relative to car driver)	3.1204	15.6
Time period constants:			
TP_11	Out AM peak, return AM peak	-3.2710	-3.2
TP_12	Out AM peak, return inter-peak	0.7175	3.4
TP_13	Out AM peak, return PM peak	2.3528	12.9
TP_14	Out AM peak, return off-peak	1.2316	6.2
TP_22	Out inter-peak, return inter-peak	-0.1591	-0.6
TP_23	Out inter-peak, return PM peak	0.4193	1.9
TP_24	Out inter-peak, return off-peak	0.2113	0.9
TP_33	Out PM peak, return PM peak	-3.2987	-3.3
TP_34	Out PM peak, return off-peak	-0.3673	-1.3
TP_41	Out off-peak, return AM peak	-2.7059	-3.7
TP_42	Out off-peak, return inter-peak	0.3857	1.7
TP_43	Out off-peak, return PM peak	0.1742	0.7
TP_44	Out off-peak, return off-peak (base combination)	0.0000	n/a

Home–primary education

Parameter	Description	Model v15 value	Model v15 t-ratio
Transfer scale			
Scale	Transfer scale	1.0000	n/a
Mode constants:			
Bus	Bus (relative to car passenger)	1.8793	2.6
Bike	Cycle (relative to car passenger)	-0.8743	-0.9
Walk	Walk (relative to car passenger)	3.8702	23.1

Home–secondary education

Parameter	Description	Model v10 value	Model v10 t-ratio
Transfer scale			
Scale	Transfer scale	1.0000	n/a
Mode constants:			
Train	Train (relative to car passenger)	0.9191	0.7
Bus	Bus (relative to car passenger)	5.6476	19.8
Walk	Walk (relative to car passenger)	5.0246	19.3

Home–tertiary education

Parameter	Description	Model v11 value	Model v11 t-ratio
Transfer scale			
Scale	Transfer scale	0.5879	9.3
Mode constants:			
CarP	Car passenger (relative to car driver)	-3.1363	-6.5
Bus	Bus (relative to car driver)	-1.3439	-3.6
Train	Train (relative to car driver)	-3.3858	-5.3
Bike	Cycle (relative to car driver)	-2.2364	-4.9
Walk	Walk (relative to car driver)	0.1112	0.3

Home–shopping

Parameter	Description	Model v18 value	t-ratio
Transfer scale			
Scale	Transfer scale	1.0000	n/a
Mode constants:			
CarP	Car passenger (relative to car driver)	-2.9241	-5.0
Bus	Bus (relative to car driver)	2.4001	4.0
Train	Train (relative to car driver)	-3.9592	-3.2
Bike	Cycle (relative to car driver)	-11.5360	-6.5
Walk	Walk (relative to car driver)	4.8135	8.7
Time period constants:			
TP_11	Out AM peak, return AM peak	-2.9810	-3.2
TP_12	Out AM peak, return inter-peak	-1.0017	-1.3
TP_13	Out AM peak, return PM peak	0.0000	n/a
TP_14	Out AM peak, return off-peak	0.0000	n/a
TP_22	Out inter-peak, return inter-peak	5.4391	10.2
TP_23	Out inter-peak, return PM peak	0.9079	1.4
TP_24	Out inter-peak, return off-peak	-8.5109	-4.8
TP_33	Out PM peak, return PM peak	-1.8810	-2.3
TP_34	Out PM peak, return off-peak	-3.5989	-3.7
TP_41	Out off-peak, return AM peak	0.0000	n/a
TP_42	Out off-peak, return inter-peak	0.0000	n/a
TP_43	Out off-peak, return PM peak	0.0000	n/a
TP_44	Out off-peak, return off-peak (base combination)	0.0000	n/a

It is noted that no shopping tours were observed to depart in the off-peak period and therefore the four time period combinations that depart in the off-peak period have been set to be unavailable and no time period constant has been estimated. These time period combinations are highlighted in grey.

Home–serve passenger

Parameter	Description	Model v12 value	Model v12 t-ratio
Transfer scale			
Scale	Transfer scale	0.8581	24.3
Mode constants:			
CarP	Car passenger (relative to car driver)	-6.8917	-11.1
Bus	Bus (relative to car driver)	-10.0390	-6.5
Walk	Walk (relative to car driver)	-2.3466	-5.3
Time period constants:			
TP_11	Out AM peak, return AM peak	0.8648	2.2
TP_12	Out AM peak, return inter-peak	-4.5283	-4.7
TP_13	Out AM peak, return PM peak	0.0000	n/a
TP_14	Out AM peak, return off-peak	0.0000	n/a
TP_22	Out inter-peak, return inter-peak	0.8243	2.2
TP_23	Out inter-peak, return PM peak	-1.1424	-2.3
TP_24	Out inter-peak, return off-peak	-8.0476	-3.9
TP_33	Out PM peak, return PM peak	0.0464	0.1
TP_34	Out PM peak, return off-peak	-2.7459	-4.1
TP_41	Out off-peak, return AM peak	-7.8749	-3.8
TP_42	Out off-peak, return inter-peak	0.0000	n/a
TP_43	Out off-peak, return PM peak	0.0000	n/a
TP_44	Out off-peak, return off-peak (base combination)	0.0000	n/a

As per the home–shopping model, time period combinations highlighted in grey were not observed in the PTP data and have therefore been set to be unavailable.

Home–other travel

Parameter	Description	Model v13 value	Model v13 t-ratio
Transfer scale			
Scale	Transfer scale	1.0000	n/a
Mode constants:			
CarP	Car passenger (relative to car driver)	-0.9299	-3.1
Bus	Bus (relative to car driver)	-2.9575	-7.0
Train	Train (relative to car driver)	-7.5426	-7.1
Bike	Cycle (relative to car driver)	-7.8023	-14.2
Walk	Walk (relative to car driver)	3.0520	10.4
Time period constants:			
TP_11	Out AM peak, return AM peak	-6.6320	-7.9
TP_12	Out AM peak, return inter-peak	-2.5442	-5.5
TP_13	Out AM peak, return PM peak	-8.8888	-7.3
TP_14	Out AM peak, return off-peak	-14.2853	-4.9
TP_22	Out inter-peak, return inter-peak	1.0302	3.2
TP_23	Out inter-peak, return PM peak	-1.0253	-2.7
TP_24	Out inter-peak, return off-peak	-5.7581	-8.3
TP_33	Out PM peak, return PM peak	-4.2235	-7.2
TP_34	Out PM peak, return off-peak	-1.6876	-4.1
TP_41	Out off-peak, return AM peak	-14.3083	-4.9
TP_42	Out off-peak, return inter-peak	-14.4960	-5.0
TP_43	Out off-peak, return PM peak	0.0000	n/a
TP_44	Out off-peak, return off-peak (base combination)	0.0000	n/a

For the two time period combinations highlighted in grey, no tours were observed in the PTP data and so the alternatives were set to be unavailable and no time period constants were estimated.

PD-based work–work tours

Parameter	Description	Model v4 value	Model v4 t-ratio
Transfer scale			
Scale	Transfer scale	1.0000	n/a
Mode constants:			
CarP	Car passenger (relative to car driver)	0.1157	0.1
Bus	Bus (relative to car driver)	3.6016	3.3
Walk	Walk (relative to car driver)	0.2108	0.2

PD-based work–other tours

Parameter	Description	Model v4	
		value	t-ratio
Transfer scale			
Scale	Transfer scale	1.0000	n/a
Mode constants:			
Bus	Bus (relative to car driver)	-0.6539	-0.6
Walk	Walk (relative to car driver)	1.7049	3.0

PD-based other–other tours

Parameter	Description	Model v4	
		value	t-ratio
Transfer scale			
Scale	Transfer scale	0.4937	5.9
Mode constants:			
CarP	Car passenger (relative to car driver)	1.4835	2.3
Walk	Walk (relative to car driver)	3.5983	6.3

Work–work detours

Parameter	Description	Model v6	
		value	t-ratio
Transfer scale			
Scale	Transfer scale	0.3976	15.9
Mode constants:			
CarP	Car passenger (relative to car driver)	-4.0872	-11.9
Bus	Bus (relative to car driver)	-3.8754	-7.4
Train	Train (relative to car driver)	-4.6161	-6.3
Walk	Walk (relative to car driver)	-3.0312	-9.4

Work–other detours

Parameter	Description	Model v9	
		value	t-ratio
Transfer scale			
Scale	Transfer scale	1.0000	n/a
Mode constants:			
CarP	Car passenger (relative to car driver)	-2.1691	-3.1
Bus	Bus (relative to car driver)	-1.7347	-1.7
Train	Train (relative to car driver)	-2.1346	-1.9
Walk	Walk (relative to car driver)	1.3967	2.3

Other–other detours

Parameter	Description	Model v9 value	Model v9 t-ratio
Transfer scale			
Scale	Transfer scale	1.0000	n/a
Mode constants:			
CarP	Car passenger (relative to car driver)	-0.9510	-0.8
Bus	Bus (relative to car driver)	1.6428	1.3
Train	Train (relative to car driver)	-9.8763	-2.3
Bike	Cycle (relative to car driver)	-6.7410	-2.7
Walk	Walk (relative to car driver)	4.9895	4.5