RAND EUROPE

South East Wales Transport Model

Frequency model results

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Preface

This report has been produced for Llywodraeth Cymru / the Welsh Government. It presents the frequency model components of the South East Wales transport model. Frequency models have been estimated for seven 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 models of simultaneous mode-destination choice, 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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Executive summary

This report documents the methodology and estimation results of the frequency model components of the South East Wales Transport Model (SEWTM). Frequency models have been estimated for seven home-based tour purposes. Models were also developed for work and non-work related non-home-based tours and detours. The socio-economic parameters that are found to be significant in explaining frequency of travel depend on the tour purpose and type but include employment status, age, household size and car availability.

Acknowledgements

We would like to acknowledge the contributions of the Welsh Government, who supplied the input data used in the estimation of the frequency models, as well as Mott MacDonald, who helped us obtain the data and are leading the wider project of which this forms a part. We would also like to acknowledge the quality assurance comments provided by Charlene Rohr and Greg Erhardt of RAND Europe. Finally, we would like to acknowledge technical oversight input from Bhanu Patruni.

Abbreviations

EB	Employer's Business
HB	Home-Based
HI	Household Interview
NHB	Non-Home-Based
NTEM	National Trip End Model
NTS	National Travel Survey
OD	Origin-Destination
PA	Production-Attraction
PD	Primary Destination
PTP	Personalised Travel Planning
SD	Secondary Destination
SEW	South East Wales
SEWTM	South East Wales Transport Model
WG	Welsh Government

1. Introduction

This report documents the estimation of the frequency model components of the South East Wales Transport Model (SEWTM). Frequency models have been developed for seven travel purposes. Travel frequency is predicted by applying two linked sub-models to predict the number of tours an individual makes on an average weekday in school term time. The first sub-model predicts whether an individual makes at least one tour in a day, and the second predicts the number of tours for a given purpose, given that the individual has made at least one tour.

Chapter 2 of this report describes the specification of the frequency models. It describes the journey purposes and the units that are modelled, and outlines the structure of the models.

Chapter 3 describes the estimation of the home-based (HB) tour frequency models. For each HB travel purpose, the observed rate of travel frequency is summarised first and then the model results are presented.

In Chapter 4 the results of the frequency model estimations for non-home-based (NHB) tours are presented. Models are estimated for two types of NHB tours: primary destination (PD)-based tours and detours during HB tours.

2. Frequency model specification

This chapter describes the specification of the frequency models. It begins with a description of the household data used for model estimation, and then goes on to discuss the travel purposes represented as well as the frequency model structures.

2.1. Household interview data

The household interview (HI) data used for model estimation were collected as part of a Personalised Travel Planning (PTP) project funded by the Welsh Government (WG). This project aimed to change mode choice by targeting households judged to have potential for increased use of sustainable transport modes. The Cardiff and Penarth data were collected over three stages:

- The baseline survey, conducted May–July 2011: the 'before' survey to measure behaviour prior to the intervention.
- The interim survey, conducted May–July 2012: the first 'after' survey, which focused on north Cardiff, the first area targeted in the intervention.
- The final survey, conducted May–July 2013: the main 'after' survey, which covered the entire project area of Cardiff and Penarth.

In each of these surveys, data were collected on all of the travel made by the individual on the survey day. It is noted that different samples of households were interviewed in the before and after surveys, thus these are *not* panel data. In addition, the PTP data delivered to RAND Europe for use in this study had the home location redacted and as such it is not possible to link individual households to SEWTM model zones.

The final PTP report (Sustrans & Socialdata 2014) states that the analysis from the interim survey was superseded by the analysis from the final survey, and so the analysis presented here has used the baseline and final surveys to represent before and after situations. Consistent with that report, the Cardiff and Penarth data is referred to as simply Cardiff in the rest of this report. Data from both the before and after surveys have been used to model travel frequency.

In addition to the Cardiff before and after data, smaller surveys were collected in 2013 in Caerphilly, Pontypridd and Barry using the same survey form.

Table 1 summarises the HI data that have been used for estimation of the frequency models.

Table 1. HI sample sizes

Dataset	Year	Households	Persons	Trips
Cardiff before	2011	548	1,380	3,987
Cardiff after	2013	575	1,313	3,726
Caerphilly	2013	168	427	1,208
Pontypridd	2013	197	430	1,169
Barry (spring)	2013	131	301	847
Barry (autumn)	2013	129	306	877
Totals		1,748	4,157	11,814

The pooled household surveys offer a reasonable sample for estimation of the frequency models, providing a broad coverage of the population and allowing exploration of how tour frequency varies across socio-economic characteristics. It is not essential that the unweighted estimation sample be representative of the population, because the models will be applied to synthetic population samples reflecting the characteristics of the whole South East Wales area in the base year and future years.

2.2. Modelling units and purposes

2.2.1. Home-based travel

HB travel has been modelled using HB tours. A *home-based tour* is a series of linked trips that start and finish at the individual's home. Modelling tours rather than trips offers a number of advantages:

- 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. In contrast trip-based approaches model each leg independently.
- NHB travel can be directly linked to HB travel; this linkage is not directly represented in trip-based approaches.
- Tour-based approaches relate more closely to an activity-based framework, recognising that travel is a derived demand that arises from the need for activity participation – the link to activities is much less clear in trip-based approaches that use an OD rather than PA framework.

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 identify the *primary destination* (PD) in order to define the main purpose of the tour.

To determine the PD, the following purpose hierarchy was employed:

1. Work
2. Employer's business
3. Education

4. Other purposes.

Thus, if a respondent made a journey to work and then a trip to visit a client (coded as an employer's business trip), the PD would be the destination for the journey to work trip. If there are ties after applying the purpose hierarchy,[1] then the destination at which the most time was spent is taken as the PD. If there are still ties after the purpose hierarchy and maximum time criteria are applied, then, of the tied destinations, the destination furthest from the home is taken as the PD. If there are still ties after the purpose hierarchy, maximum time and maximum distance criteria have been applied, then the first tied destination visited is taken as the PD.

Most tours observed in the household interview (HI) data are *full tours*, which means that both an outward leg from the home to the PD and a return leg from the PD back to the home have been recorded in the HI data. An *outward half tour* is where a movement from the home to the PD is recorded, but no corresponding return movement is observed (this might occur, for example, if an individual leaves the home on the survey day to visit a friend and stays overnight at their friend's house). Similarly a *return half tour* is a movement from the PD back to home where no corresponding outward leg is recorded (for example a nightshift worker returning home after their shift).

Over 98 per cent of the HB tour types observed in the HI data are full tours:

- 5,001 (98.4 per cent) full tours
- 79 (1.6 per cent) outward half tours
- 76 (1.5 per cent) return half tours.

Half tours can occur for two reasons: firstly, because the full tour cannot be recorded within the survey day; and secondly, because of coding errors, where individuals have recorded only partial information about their trip chain. As the survey day recorded in the HIs actually covered a period of 29 hours (starting at 0:00 hours on one day and finishing at 05:00 hours on the next) this allowed most full tours to be completed within the survey period, resulting in a high percentage of full tours being recorded.

To develop the mode-destination models, only full tours have been included because it was judged that modelling the small numbers of half tours was not justified given their small number and because RAND Europe's experience is that higher levels of error are associated with half tours compared to full tours. However, half tours are important for frequency modelling, since if they are all excluded the frequency models will slightly under-predict total travel. Therefore the approach that has been used for the frequency models is to include *all full tours and outward half tours*. Each outward half tour is treated as equivalent to a full tour, essentially balancing the outward and return tours.

Given that the survey day runs for 29 hours, a potential concern would be that the models over-represent travel on an average weekday (i.e. a 24-hour period) in school term time, particularly for sub-purposes such as social travel where some travel is made in the early hours of the morning. However, the consequence of including the five hour period in the early hours of the following day is that some tours that would be half tours with a 24-hour day are recorded as full tours with a 29-hour day because the

[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.

return leg occurs early the next day. We ran a test to confirm that the frequency rates were not being biased by the inclusion of this additional five-hour period. Specifically we re-ran the tour-building using a 24-hour day running from midnight and this test confirmed that the *sum of full tours and outward half tours* was the same as obtained using the 29-hour day definition. The reason for this is that some tours that are outward half tours using a 24-hour day definition became full tours using a 29-hour definition, and because the frequency models are estimated from the sum of full and outward tours there is no difference in the modelled tour rate. It is noted that for the mode-destination models, where only full tours are included in the modelling, we benefit from the slightly larger sample sizes that result from using a 29-hour day.

In summary we have verified that using the full 29-hour data does not bias the frequency modelling, and it maximises the volume of tours available for mode-destination estimation.

Tour frequency models have been developed for seven different HB tour purposes:

- Commute
- Primary education
- Secondary education
- Tertiary education
- Shopping
- Escort, including escort to school and to other destinations
- Other travel.

To avoid any misrepresentation of tour-making for different purposes in the SEWTM, while maintaining the overall impact of travel on the transport network, a small amount of recoding was required. The following HB tours recorded in the survey were reclassified as home–other tours:

- Commuting or employer's business tours made by individuals who are looking for work, have home duties or are retired or pensioners.
- Escort tours made by children aged 16 years or under; only escort tours made by adults were explicitly modelled.
- Education tours made by children aged 5 years or under.[2]

Although tours on employer's business were recorded in the HI, there were insufficient data to develop a frequency model for this trip purpose. The approach that we have developed to overcome this issue is described in Chapter 5.

2.2.2. Non-home-based travel

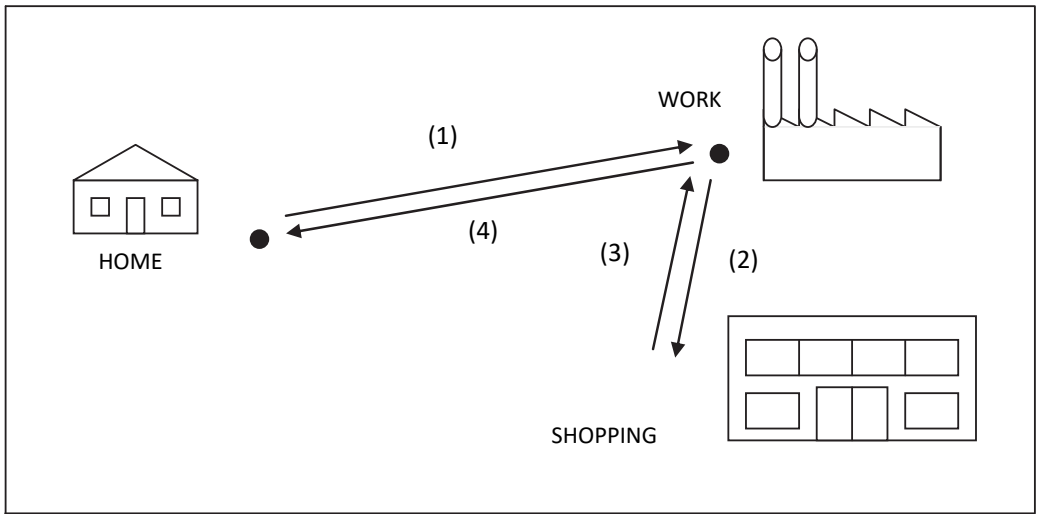
Once the HB tours had been identified in the HI data, the NHB travel associated with those HB tours was identified. Two types of NHB travel have been represented, each linked to full HB tours:

[2] It is noted that most children will start school in the September of the school year in which they turn 5, and that therefore the average age of starting school will be about 4½. However, in the PTP data ages are only recorded to the nearest year, so the cut off has to be 4 or 5. Since the model will be applied incrementally, this is not crucial as it will not have a significant effect on the growth rate applied to the base matrices.

- PD-based tours – a series of linked trips starting and finishing at the same PD location; for example, if an individual goes shopping at lunchtime during their work day.
- NHB detours made during the outward or return legs of HB tours – a single trip to or from the PD; for example, if an individual makes a diversion on their journey back home to pick up a child from school.

These two cases are illustrated by the examples in the following figures. In Figure 1, trips (2) and (3) form the PD-based tour and trips (1) and (4) form the HB tour. In Figure 2, 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 2).

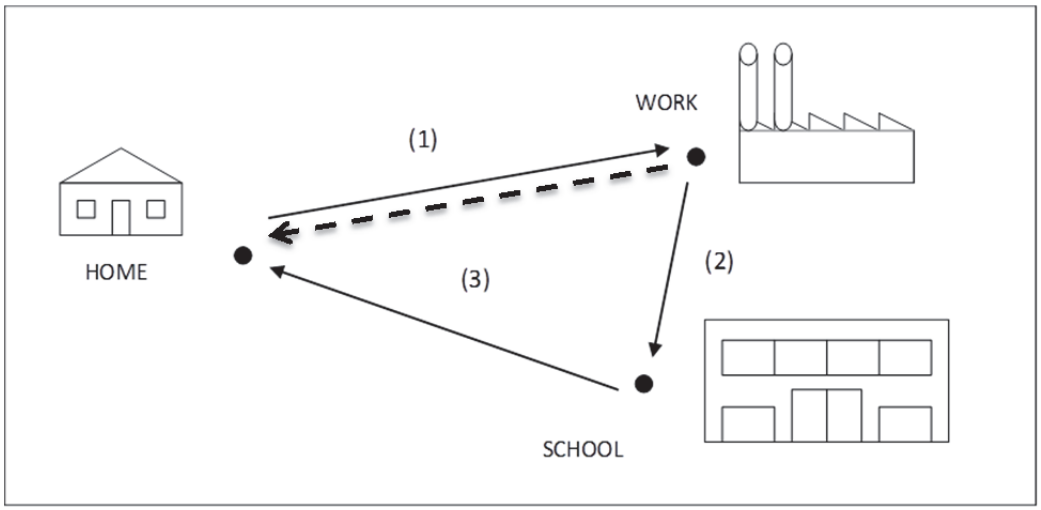
Figure 1. PD-based tour example



If multiple destinations are visited during the PD-based tour, a single *secondary destination* (SD) is identified, and a direct return tour between the PD and SD is modelled. Similarly, if an individual detours to more than one destination during an outward or return HB tour leg, a single SD is identified in that direction, and a direct trip between the PD and the SD is modelled. In both cases, the SD is identified using the same set of rules used to determine the PD, with a purpose hierarchy applied first, and then subsequent tie-break rules are applied if required. The number of cases where individuals visit multiple SDs is low (in the Cardiff tour data, for example, just 3 per cent of PD-based tours involve visits to more than one SD). Therefore the additional complexity that would result from separately modelling multiple SD visits during a single PD-based tour was judged not to be justified.

Figure 2 illustrates an example of a parent picking up a child from school on their way home from work. This is represented as a NHB detour to a school SD on the return leg of a HB tour.

Figure 2. NHB detour example



Only full PD-based tours are modelled, because only NHB travel made within HB travel is modelled. Any PD-based half tours must be data coding errors because an individual has to return to the PD before travelling back home again.

Three types of PD-based travel have been modelled, taking advantage of the hierarchy of purposes, which means that when a tour is work-related,[3] the work destination is always the PD and cannot be an SD. Hence, if the PD is not work-related, the SD is also not work-related:

- PD work–work: PD-based tours made from work-related PDs to work-related SDs
- PD work–other: PD-based tours made from work-related PDs to other SDs
- PD other–other: PD-based tours made from other purpose PDs to other SDs.

Three further purposes have been defined to model NHB detours:

- NHB work–work: detours made during work-related PD tours to work-related SDs
- NHB work–other: detours made during work-related PD tours to other purpose SDs
- NHB other–other: detours made during other purpose PD tours to other purpose SDs.

2.3. Model structure

Frequency models have been developed to predict the number of tours made by a traveller on an average weekday in school term time for a given travel purpose.

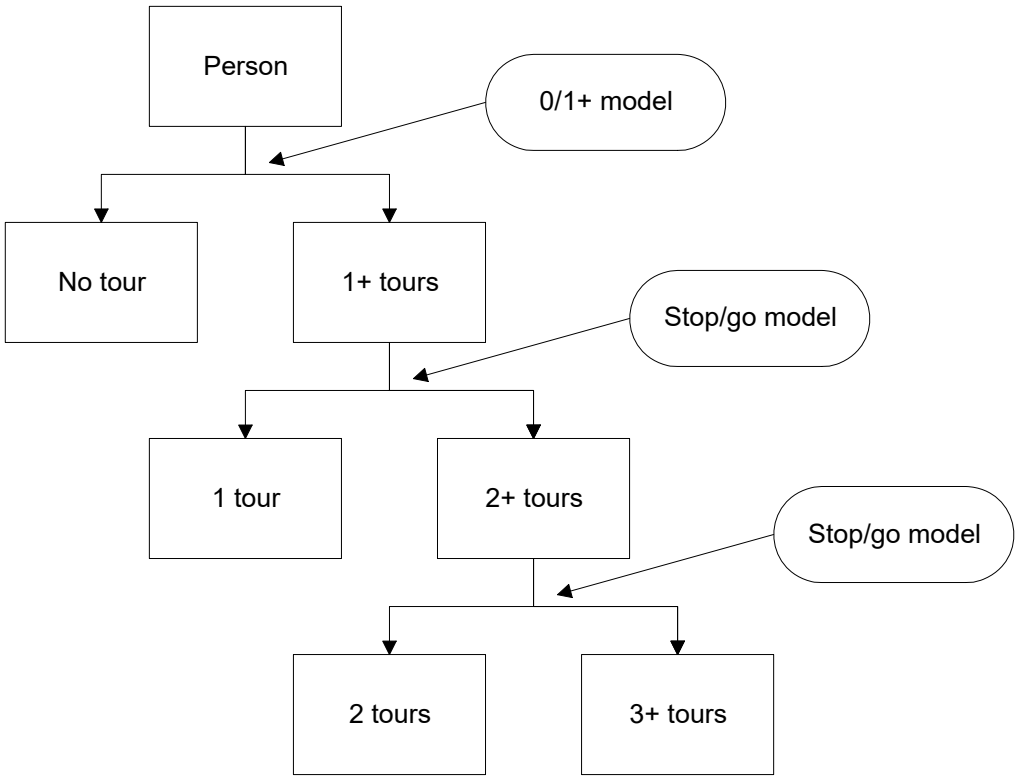
[3] 'Work-related' here means either a tour to an individual's main workplace or a tour to a destination on employer's business.

2.3.1. Tour model structure

The tour model structure for HB tours combines a sub-model to predict whether any tours will be made (0/1+ model) with a second sub-model to predict the extent to which additional tours are made, given at least one tour is made (stop/go model). The two sub-models are estimated together in a single model run for run efficiency.

The model structure is illustrated in Figure 3, which is extended to include the rare travellers observed to make four or more tours for a given purpose in a day.

Figure 3. Tour frequency model structure



In the 0/1+ model, utilities are defined for the 'no tours' alternative and therefore the model terms reflect the increased probability of *not* making a tour. Negative model terms imply an increased probability of making a tour.

In the stop/go model, utilities are defined for the stop alternatives (one tour and two tours in Figure 3) and therefore in this model the model terms reflect the probability of *not* making additional tours. This means that negative model terms imply an increased probability of making multiple tours. In the example presented in Figure 3, no more than two tours are observed per individual on a given day. For each model purpose, the structure for the stop/go model is tailored to reflect the maximum number of tours observed.

It is noted that the utility functions are identical on the 1 tour, 2 tours etc. alternatives, as the probability of stopping is assumed to be constant for a given individual.[4]

A discussion of possible model forms is provided in Daly & Miller (2006). They conclude that the probability of making one or more trips should be modelled separately from the probabilities of making multiple trips, and that the accessibility linkage should be achieved using a logsum to ensure consistency with a utility maximisation framework. The models developed for South East Wales use separate models for the 0/1+ and multiple trips decisions, but unlike the PRISM West Midlands models they do not represent a direct accessibility linkage because of the complexities of modelling destination choice using the South East Wales data.[5]

In addition to constant terms, which ensure that the tour rates observed in the 2009–2012 HI data are reproduced exactly, socio-economic terms were tested to represent differences in tour rates according to the personal and household-level characteristics of individuals. Starting from the constants only model, the fit across different socio-economic groups was examined and additional terms were then added to the model to take account of observed variation. The socio-economic variables considered in this process were identified based on our experience of developing frequency models, such as the PRISM model, and included terms related to car ownership and competition for car use, as well as employment status, age and household size. Based on our experience with other models, it is important to test the impact of car availability on travel frequency.

2.3.2. Detour model structure

The detour models predict the binary choice between 'no detour' and 'detour' alternatives. The utilities terms are placed on the 'no detour' alternative and therefore a negative model term indicates that an individual is more likely to make a detour.

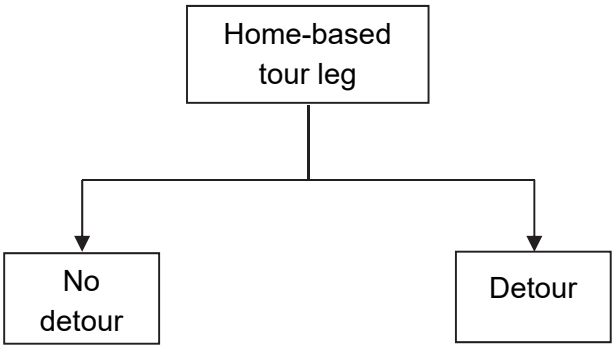
Separate detour models have been estimated for detours made during the outward and return legs of HB tours. This is because we observe that, for some tour purposes, individuals are more likely to make detours during the return legs. The higher detour rate during return legs reflects travel patterns such as individuals visiting the supermarket on the way home from work, or participating in evening social activities near their workplace before returning home.

Figure 4 illustrates the detour frequency model structure. As discussed in Section 2.1.2, only one detour per tour leg is modelled. A detour on the way home from work to pick-up children from school and then going shopping would be classified as a NHB work–other detour in this framework. According to the tour purpose hierarchy, the PD is work and the SD is shopping, and for the NHB modelling, tour purposes are categorised as either work-related or for other purposes only.

[4] $P(1|1+) = P(2|2+) = P(3|3+)$, etc.

[5] These are discussed in the mode-destination estimation report.

Figure 4. Detour frequency model structure



3. Home-based frequency models

This chapter presents the models for each of the seven HB purposes represented in the SEWTM. Employer's business is also discussed, although as the discussion of sample sizes will demonstrate, there were insufficient data to develop a frequency model for this tour purpose.

3.1. Home-based commute

3.1.1. Estimation sample

To determine the appropriate definition of the estimation sample for the commute frequency model, the number of tours made by adults was cross-tabulated with the employment status of the individual. It is noted that in the PTP data a given individual could only give a single answer to the employment status question, for example a student with a part-time job could either record student or part-time worker but not both. The resulting cross-tabulation is presented in Table 2.

Table 2. Weekday commute tours made by employment status for adults aged over 16

Employment status	Commute tours				Total
	0	1	2	3	
home duties	133	2	1	0	136
	97.8 %	1.5 %	0.7 %	0.0 %	100.0%
retired or aged pensioner	619	4	2	1	626
	98.9 %	0.6 %	0.3 %	0.2 %	100.0%
looking for work	70	0	0	0	70
	100.0 %	0.0 %	0.0 %	0.0 %	100.0%
college	32	8	0	0	40
	80.0 %	20.0 %	0.0 %	0.0 %	100.0%
university	63	17	0	0	80
	78.8 %	21.3 %	0.0 %	0.0 %	100.0%
part-time or casual work	117	177	11	1	306
	38.2 %	57.8 %	3.6 %	0.3 %	100.0%
full-time work	147	681	21	1	850
	17.3 %	80.1 %	2.5 %	0.1 %	100.0%
Total	1,181	889	35	3	2,108
	56.0 %	42.2 %	1.7 %	0.1 %	100.0 %

Nearly all (90 per cent) of work tours are made by persons who are in either full-time or part-time employment. It is also observed that 20 per cent of college students and 21 per cent of university students make one work tour per day, respectively. Thus, as significant numbers of commuting tours are made by these two student groups, they have been included within the population able to make commute tours in the commute frequency model.

Among individuals who are looking for work, have home duties or are retired or pensioners, 98.8 per cent made no commute tours on the survey days. These have been excluded from the analysis of commute tours. However, to avoid underestimating the total volume of travel, the very low numbers of 'commute' tours recorded for these person types have been reclassified as home–other travel and included in the frequency model estimated for that purpose. A small number of commute tours recorded by secondary school pupils aged over 16 (not shown in Table 3) were also reclassified as home-other tours.

In summary, the commute frequency model has been estimated from the sample of adults with one of the following adult status groups:

- College
- University

- Part-time or casual work
- Full-time work.

In the discussion below these groups are termed either workers or students.

Table 3 tabulates the number of commute tours made per weekday in the South East Wales data, and for comparison purposes also presents the corresponding tabulation from the PRISM 2011 base commute frequency model.

Table 3. Commute tours per weekday in South East Wales and West Midlands data

Number of tours	South East Wales data, 2011 & 2013 Tours by workers and students		PRISM West Midlands data, 2009–2012 Tours by workers and students	
0	359	28.1 %	2,912	41.0 %
1	883	69.2 %	4,116	57.9 %
2	32	2.5 %	74	1.0 %
3	2	0.2 %	4	0.1 %
Total	1,276	100.0 %	7,106	100.0 %
Mean tour rate	0.75		0.60	

The overall tour frequency rate of 0.75 is noticeably higher in the South East Wales data compared to the West Midlands, with a noticeably higher fraction of workers and students in the latter observed to make no work tours on the survey day. One possible explanation for this is differences in the distributions of the two populations across adult status groups. However, even when the analysis is restricted to full-time workers the difference persists, with tours rates of 0.85 and 0.73 for the South East Wales and West Midlands datasets respectively. Both sets of numbers related to a weekday in school term time and so this does not explain the difference.

Subsequent analysis demonstrated that the apparently higher commute tour frequency rates in the South East Wales data compared to the PRISM West Midlands data is as a result of some employer's business travel being miscoded as commute. Chapter 5 presents analysis that demonstrates this fact and shows the adjustments that have been applied to correct for the miscoding.

3.1.2. Model results

The parameters in the frequency model are summarised in Table 4.

Table 4. Commute frequency model results

Parameter name	Sub-model	Parameter		Definition
		estimate	t-ratio	
NoTour	0/1+	1.335	5.9	Constant to ensure overall fraction of individuals making at least one tour is replicated
FTworker	0/1+	-2.952	-12.1	Full -ime workers are less likely to make zero commute tours, i.e. more likely to make commute tours, than college or university students
PTworker	0/1+	-1.911	-7.5	Part-time workers are more likely to make commute tours than college or university students, but less likely than full-time workers
AgeGt60	0/1+	0.743	3.1	Individuals over the age of 60 are less likely to make commute tours than individuals aged 17 to 60 years
stop	stop/go	3.328	19.1	Constant to ensure observed rate of multiple tour-making is replicated

As would be expected, full-time workers are much less likely to make zero tours than college or university students. Part-time workers are also less likely to make zero tours, but as would be expected the effect is not as strong as that for full-time workers because a higher fraction of part-time workers is observed to make zero tours.

The AgeGt60 parameter reflects the fact that individuals aged over 60 have lower overall tour rates on average than individuals aged 17–60, over and above differences related to the full-time and part-time worker mix.

Just 2.7 per cent of individuals made two or more tours, and therefore there are not many observations available to identify socio-economic effects in the stop/go model.

3.2. Home-based employer's business

Table 5 tabulates the number of employer's business (EB) tours observed in the estimation sample.

Table 5. Tours made on employer's business per weekday by workers and adult students

Tours	Count	Per cent
0	1,268	99.4 %
1	7	0.5 %
2	1	0.1 %
Total	1,276	100.0 %

The number of EB tours recorded in the HI survey is extremely low with a tour rate of just 0.007, compared to the PRISM data (which is for another UK conurbation) where the EB tour rate is 0.08, i.e. more than ten times higher. The NTS data for Wales (2002–2010) gives trips rather than tours, so tour rates cannot be compared; however, the ratio of business to work trips is 0.24 in this data compared to just 0.007 in the HI data.

Given that the rate of employer's business tours/trips is dramatically lower than in the two comparison datasets, it seems likely that the HI data under-represent actual EB tour-making in the region. Under-reporting of EB trips in household interviews surveys is a common problem due to confusion, for respondents, between commuting and employer's business travel. The same issue was encountered during the development of the original version of the PRISM model in the early 2000s, as discussed in Fox et al. (2004). In the PRISM analysis it was discovered that a significant fraction of 'work' trips were made to a location other than the individual's main workplace due to confusion on the part of respondents between what was meant by 'work' and 'employer's business' purposes.

Given the very low EB tour rate in the South East Wales HI data, we were not able to develop an EB tour frequency model. Instead, we transferred the PRISM HB EB model to the SEWTM context. The approach used to make the transfer is documented in Chapter 5.

3.3. Home-based primary education

3.3.1. Estimation sample

The primary education frequency model has been estimated from the sample of children in the 5–11 age band, who were also separately classified as currently being at primary school. Table 6 summarises the observed numbers of primary education tours made per child on an average weekday.

Table 6. Primary school tours per weekday made by children in the 5–11 age group

Tours	Count	Per cent
0	30	15.9 %
1	154	81.5 %
2	5	2.6 %
Total	189	100.0 %

Only data collected on weekdays during school term time were included in the analysis. Almost 85 per cent of primary-aged children were observed to make at least one school tour on the survey day. Just 2.6 per cent of children made more than one primary school tour, so clearly few pupils return home for lunch during the school day in South East Wales. The overall tour frequency rate is 0.868 primary education tours per weekday in school term time.

We can only speculate on the possible explanations for this seemingly low 85 per cent value. Firstly, although school holidays have been excluded from the survey, additional school specific closures for staff

training could not be controlled for. Secondly, there may be children who have been classified as primary school children in the survey who attend non-compulsory education on a part-time basis. Our understanding is that compulsory education in Wales commences in the term after a child turns 5 years of age, although many start in the reception class at age 4. In the survey, age is based on birth year only and it is therefore not possible to align completely with the school year. Hence with a lower age limit (cut off) of 5 years of age, we may be including some children not yet of compulsory school age. However, the model will be applied to the same age category and therefore the overall trip rate should be appropriate.

3.3.2. Model results

Table 7 presents the primary education tour frequency model results.

Table 7. Primary education frequency model results

Parameter	Sub-model	Parameter		Definition
		estimate	t-ratio	
NoTour	0/1+	-1.668	-8.4	Constant to ensure overall fraction of individuals making at least one primary school tour is replicated
stop	stop/go	3.459	7.6	Constant to ensure observed rate of multiple tour-making for primary school tours is replicated

No socio-economic parameters could be identified in the model and the final model specification shown in Table 7 includes constants only. As the model does not represent variation in tour-making between different socio-economic segments it will therefore predict the same average tour frequency rate in the base year and all future scenarios.

3.4. Home-based secondary education

3.4.1. Estimation sample

The secondary education frequency model has been estimated from the sample of children attending school in the 12–18 age band,[6] who have also separately classified as currently being in secondary education. Thus sixth form students are included in the sample, but students in the 17–18 age group attending other forms of education are not; tours by this latter group are modelled as tertiary education tours.[7] Table 8 summarises the observed numbers of secondary education tours made per weekday in school term time.

[6] As for primary education, age was used to exclude observations from the analysis for which the education status had been miscoded. This approach is not perfect as (calendar year) age does not align with the school year, but the method was applied consistently for each education category.

[7] Our understanding is that the school leaving age in Wales is currently 16 years (see https://www.gov.uk/know-when-you-can-leave-school). Individuals above this age choosing to attend sixth form have been classified as being in

Table 8. Secondary school tours per weekday for children aged 12–18

Tours	Count	Per cent
0	34	15.9 %
1	154	81.5 %
2	1	2.6 %
Total	189	100.0 %

Only data collected during school term time were included in the analysis. However, as the survey was mainly undertaken in the summer term, this may have coincided with the exam period, explaining the relatively high number of pupils not making any school tours on the survey days, particularly sixth form students. Nevertheless, 82 per cent of children in secondary education were observed to make at least one school tour on the survey day.

3.4.2. Model results

Table 9 presents the secondary education frequency model results.

Table 9. Secondary education frequency model results

Parameter name	Sub-model	Parameter		Definition
		estimate	t-ratio	
NoTour	0/1+	-2.027	-7.9	Constant to ensure overall fraction of individuals making at least one secondary education tour is replicated
6thform	0/1+	5.041	5.0	Secondary school students aged 17 or 18 years are less likely to make education tours (more likely to make zero tours) than children aged 12 to 16
stop	stop/go	1.602	4.0	Constant to ensure observed rate of multiple tour-making for secondary education tours is replicated

The age-related term (6thform) in the 0/1+ model for secondary education tours indicates that tour rates are lower for sixth form students in the 17–18 age group than for those aged 12–16. Furthermore, as only a few individuals make more than one tour, the only significant parameter that has been identified in the stop/go model is the constant to ensure that the observed tour frequency rate is replicated by the model.

secondary education, while those attending other forms of education make tertiary education tours; these may be college students or adults with other employment classifications. We note here for completeness that the proportion of these groups in full-time education may increase from that observed in the survey should the school leaving age rise from 16 years.

3.5. Home-based tertiary education

3.5.1. Estimation sample

To determine the appropriate population for tertiary education travel, a cross-tabulation was made of the number of tertiary education tours made and the status of the individual – this is presented in Table 10.

Table 10. Weekday tertiary education tours by employment status for adults aged over 16

Adult status	Tertiary education tours				Total
	0	1	2	3	
home duties	131	5	0	0	136
	96.3%	3.7%	0.0%	0.0%	100.0%
retired or aged pensioner	621	5	0	0	626
	99.2%	0.8%	0.0%	0.0%	100.0%
looking for work	64	6	0	0	70
	91.4%	8.6%	0.0%	0.0%	100.0%
college	16	24	0	0	40
	40.0%	60.0%	0.0%	0.0%	100.0%
university	52	24	3	1	80
	65.0%	30.0%	3.8%	1.3%	100.0%
part-time or casual work	300	6	0	0	306
	98.0%	2.0%	0.0%	0.0%	100.0%
full-time work	847	3	0	0	850
	99.6%	0.4%	0.0%	0.0%	100.0%
Total	2,031	73	3	1	2,108
	96.3%	3.5%	0.1%	0.0%	100.0%

Most tertiary education tours are made by full-time college or university students. However, tertiary education tours are also made by all other status groups and so all adults aged over 16, except those aged 16–18 in secondary education, were included as the population for the tertiary education frequency model. Separate socio-economic terms were tested to account for differences in tour frequency between different status groups.

The final tertiary education estimation sample is summarised in Table 11.

Table 11. Tertiary education tours per weekday for adults aged over 16

Tours	Count	Per cent
0	2,031	96.3 %
1	73	3.5 %
2	3	0.1 %
3	1	0.0 %
Total	2,108	100.0 %

The average tour frequency rate is just 0.039 tertiary education tours per adult per weekday in school term time. However, for college and university students the rate is over ten times higher, at 0.475 tours per weekday in school term time. Only four adults made two or more tertiary education tours on the survey day and therefore there were very few data available to identify socio-economic terms for the stop/go model.

3.5.2. Model results

Table 12 presents the tertiary education frequency model results.

Table 12. Tertiary education frequency model results

Parameter name	Sub-model	Parameter		Definition
		estimate	t-ratio	
notour	0/1+	3.982	18.2	Constant to ensure overall fraction of individuals making at least one tertiary education tour is replicated
FTwork	0/1+	1.821	2.9	Full-time workers are less likely to make tertiary education tours (more likely to make zero tours) than those with duties at home, looking for work or retired
univ	0/1+	-3.033	-8.7	University students are more likely to make tertiary education tours than those with duties at home, looking for work or retired, but less likely than college students
college	0/1+	-4.304	-11.0	College students are more likely to make tertiary education tours than those with duties at home, looking for work or retired
age2230	0/1+	-0.732	-2.0	Adults aged 22–30 are more likely to make tertiary education tours than those in other age groups but less likely than college and university students who are mainly younger
stop	stop/go	2.734	5.9	Constant to ensure observed rate of multiple tour-making for tertiary education is replicated

The terms for full-time workers, university students and college students in the 0/1+ model are plausible, reflecting the fact that college and university students are more likely to make tertiary education tours than other groups, and that full-time workers have the lowest overall tertiary education tour rates.

The age term (age2230) also supports a pattern of decreasing likelihood of participating in tertiary education with age, as most college and university students are under 25 years old. This age effect is over and above the differences in the mix of population between full-time working, university students and college students with age.

3.6. Home-based escort

3.6.1. Estimation sample

Table 13 cross-tabulates the number of weekday escort tours made by age category to inform the decision as to which age groups to include in the estimation sample for the frequency model.

Table 13. Weekday escort tours made by age category

Age band	Escort tours					Total
	0	1	2	3	4	
under 5	63	16	6	2	1	88
	71.6 %	18.2 %	6.8 %	2.3 %	1.1 %	100.0%
5–11	183	12	2	2	0	199
	92.0 %	6.0 %	1.0 %	1.0 %	0.0 %	100.0%
12–14	78	0	1	0	0	79
	98.7 %	0.0 %	1.3 %	0.0 %	0.0 %	100.0%
15–16	78	0	0	0	0	78
	100.0 %	0.0 %	0.0 %	0.0 %	0.0 %	100.0%
17–20	129	1	1	0	0	131
	98.5 %	0.8 %	0.8 %	0.0 %	0.0 %	100.0%
21–24	112	2	0	0	0	114
	98.2 %	1.8 %	0.0 %	0.0 %	0.0 %	100.0%
25–30	146	4	5	1	0	156
	93.6 %	2.6 %	3.2 %	0.6 %	0.0 %	100.0%
31–39	90	8	5	3	0	106
	84.9 %	7.5 %	4.7 %	2.8 %	0.0 %	100.0%
40–44	107	11	19	6	0	143
	74.8 %	7.7 %	13.3 %	4.2 %	0.0 %	100.0%
45–49	158	21	19	3	1	202
	78.2 %	10.4 %	9.4 %	1.5 %	0.5 %	100.0%
50–54	157	21	9	0	0	187
	84.0 %	11.2 %	4.8 %	0.0 %	0.0 %	100.0%
55–59	183	8	4	1	0	196
	93.4 %	4.1 %	2.0 %	0.5 %	0.0 %	100.0%
60–64	176	13	1	1	0	191
	92.1 %	6.8 %	0.5 %	0.5 %	0.0 %	100.0%
65 and above	156	7	5	0	0	168
	92.9 %	4.2 %	3.0 %	0.0 %	0.0 %	100.0%
Total	534	23	4	4	0	565
	94.5 %	4.1 %	0.7 %	0.7 %	0.0 %	100.0%

Table 13 shows some escort tours reported as being made by children aged 16 or under. Escort tours made by children under 5 years are likely to have arisen either from a misunderstanding of the survey or were undertaken in the company of another older escort (e.g. a mother with baby accompanying a child to school), while those in the 5–11 age group could be escorting siblings to school. To avoid any misrepresentation of the data, these trips have been reclassified as home–other, ensuring that their impact on the South East Wales transport networks is represented, and we only consider adult (aged over 16 years) escort trips in the home–escort frequency model. This is consistent with the PRISM model approach. Furthermore, no distinction is made between school escort tours and those made for other purposes.

The final estimation sample for the escort frequency model is presented in Table 14.

Table 14. Escort tours made per weekday by adults aged over 16

Tours	Count	Per cent
0	1,898	90.0 %
1	119	5.6 %
2	71	3.4 %
3	19	0.9 %
4	1	0.0 %
Total	2,108	100.0 %

The mean escort tour frequency rate for persons aged over 16 is 0.150 escort tours per weekday in school term time. Some 90 per cent of adults make no escort tours but 4.3 per cent make at least two. It should be noted that these tour rates are the rates per adult in the household; we observe that in a multi-adult household it is likely that only one adult makes the escort tours. Moreover, children are aged 5–16 and many children aged 11 and above travel to school alone.

3.6.2. Model results

Table 15 presents the escort tour frequency model results.

Table 15. Escort tour frequency model results

Parameter name	Sub-model	Parameter		Definition
		estimate	t-ratio	
notour	0/1+	4.880	15.6	Constant to ensure overall fraction of individuals making at least one escort tour is replicated
hhsizeeq1	0/1+	1.450	3.1	Individuals from households with only one member are less likely to make an escort tour (more likely to make zero tours) than households with two or three members
hhsizege4	0/1+	-0.863	-4.8	Individuals from households with at least four members are more likely to make an escort tour than households with two or three members
licence	0/1+	-1.030	-4.3	Adults that hold a driving licence are more likely to make an escort tour than non-licence holders
athome	0/1+	-2.190	-8.6	Individuals with home duties are more likely to make an escort tour than full-time workers and university or college students
retired	0/1+	-1.589	-5.9	Retired individuals or pensioners are more likely to make an escort tour than full-time workers and university or college students but less likely than those with home duties
betwjobs	0/1+	-1.506	-3.8	Individuals looking for a job are more likely to make an escort tour than full-time workers and university or college students but less likely than those with home duties
ptwork	0/1+	-1.124	-5.3	Part-time workers job are more likely to make an escort tour than full-time workers and university or college students but less likely than those with home duties, looking for a job or retired individuals
age3150	0/1+	-1.448	-7.3	Adults aged 31 to 50 are more likely to make an escort tour than others aged 17 or above
stop	stop/go	1.175	7.0	Constant to ensure observed rate of multiple escort tours is replicated
female1	stop/go	-1.253	-5.1	Females are more likely to make more than one escort tour than males

A number of model parameters have been identified in the escort frequency model, representing the variation in escort tour frequency across status, age band, car availability, gender and household size segmentations.

Firstly, larger households are more likely to make escort trips, reflecting that these are also more likely to contain children. Secondly, in terms of employment status, individuals are more likely to make escort tours if they are not working full time or at college or university. Driving licence holding was also found

to increase the likelihood of escort trips. Finally, there were sufficient data in the stop/go model to show that women are more likely to make multiple escort tours than men. It is noteworthy that this term was not significant in the 0/1+ model.

3.7. Home–shopping

3.7.1. Estimation sample

Table 16 presents a cross-tabulation of the number of shopping tours made by age.

Table 16. Weekday shopping tours made by age category

Age band	Shopping tours				Total
	0	1	2	3	
under 5	*88*	*0*	*0*	*0*	*88*
	100.0 %	*0.0 %*	*0.0 %*	*0.0 %*	*100.0 %*
5–11	198	1	0	0	199
	99.5 %	0.5 %	0.0 %	0.0 %	100.0 %
12–14	*75*	4	0	0	*79*
	94.9 %	*5.1 %*	0.0 %	0.0 %	100.0 %
15–16	*72*	6	0	0	*78*
	92.3 %	*7.7 %*	0.0 %	0.0 %	100.0 %
17–20	118	13	0	0	131
	90.1 %	9.9 %	0.0 %	0.0 %	100.0 %
21–24	102	12	0	0	114
	89.5 %	10.5 %	0.0 %	0.0 %	100.0 %
25–30	141	15	0	0	156
	90.4 %	9.6 %	0.0 %	0.0 %	100.0 %
31–34	95	11	0	0	106
	89.6 %	10.4 %	0.0 %	0.0 %	100.0 %
35–39	120	21	2	0	143
	83.9 %	*14.7 %*	1.4 %	0.0 %	100.0 %
40–44	172	29	1	0	202
	85.1 %	14.4 %	0.5 %	0.0 %	100.0 %
45–49	156	31	0	0	187
	83.4 %	16.6 %	0.0 %	0.0 %	100.0 %
50–54	160	35	1	0	196
	81.6 %	17.9 %	0.5 %	0.0 %	100.0 %
55–59	155	35	1	0	191
	81.2 %	18.3 %	0.5 %	0.0 %	100.0 %
60–64	108	50	9	1	168
	64.3 %	29.8 %	*5.4 %*	0.6 %	100.0 %
65 and above	325	219	19	2	*565*
	57.5 %	38.8 %	3.4 %	0.4 %	100.0%
Total	2085	482	33	3	2603
	80.1%	18.5 %	1.3 %	0.1 %	100.0 %

All age groups except the under 5s are observed to make shopping tours, and therefore the shopping frequency model has been estimated from the sample of persons aged 5 and above.

The final shopping frequency estimation sample is summarised in Table 17.

Table 17. Shopping tours per weekday made by individuals aged 5 and above

Tours	Count	Per cent
0	1,989	79.4 %
1	481	19.2 %
2	33	1.3 %
3	3	0.1 %
Total	2,506	100.0 %

The average shopping tour frequency rate is 0.222 tours per average weekday in school term time. Just 1.4 per cent of individuals are observed to make two or more shopping tours and this means that there is limited data to support estimation of socio-economic parameters in the stop/go model.

3.7.2. Model results

Table 18 presents the shopping tour frequency model results.

Table 18. Shopping tour frequency model results

Parameter name	Sub-model	Parameter		Definition
		estimate	t-ratio	
NoTour	0/1+	2.212	21.1	Constant to ensure overall fraction of individuals making at least one shopping tour is replicated
carnolic	0/1+	0.558	3.6	Individuals from car-owning households who are not licence holders are less likely to make a shopping tour than individuals who are licence holders and individuals in households without a car
PTime	0/1+	-1.044	-6.2	Part-time workers are more likely to make a shopping tour than full-time workers or students
betwjobs	0/1+	-1.611	-5.8	Individuals looking for a job are more likely to make a shopping tour than full-time workers, children and university or college students
retired	0/1+	-1.354	-5.9	Retired individuals or pensioners are more likely to make a shopping tour than full-time workers, children and university or college students but less likely than those looking for jobs or with home duties
athome	0/1+	-1.442	-6.8	Individuals with home duties are more likely to make a shopping tour than full-time workers, children and university or college students
agegt60	0/1+	-0.681	-3.2	Individuals over the age of 60 are more likely to make a shopping tour than those in the age range 13 to 60
agelt13	0/1+	1.999	2.8	Children aged 12 or under are less likely make a shopping tour than those in the age range 13 to 60
stop	stop/go	2.586	15.6	Constant to ensure observed rate of multiple tour-making is replicated

The parameters identified in the shopping frequency model reflect that shopping tour frequencies vary across age group, employment status and car availability segmentations.

The 'carnolic' parameter captures a car availability interaction in car-owning households effect whereby individuals in car-owning households without a licence are less likely to make a tour than both individuals with a licence with a car and individuals from households without a car. In car-owning households it is more likely that individuals with a licence will drive to make a shopping tour. In households without a car there is still a need to shop and so they do not have shopping tour frequency rates as low as those observed for non-licence holders in car-owning households.

The parameters for part-time workers, individuals who are between jobs, retired persons and individuals with home duties summarised in Table 18 capture expected variation in shopping tour rates between these different groups. The reference group for these terms is collectively full-time workers, children, university students and college students.

The age effects are also consistent with intuition, with children aged 12 and under having the lowest shopping frequency rates, and retired persons having higher tour frequency rates, which is consistent with the greater time they have available on an average weekday to make shopping tours.

3.8. Home–other travel

3.8.1. Estimation sample

Table 26 presents a cross-tabulation of the number of home–other travel tours made by age band. The home–other travel purpose covers travel to PDs where the purpose is not work, business, education, shopping or escort. In addition to the home–other travel tours identified from the tour building process, as noted in previous sections, a small numbers of tours have been reclassified as home-other travel from other tour purposes added to the tour counts for the home–other estimation sample. These comprise: commute and employer's business tours made by individuals whose status code is between jobs, retired, with home duties or in secondary education; and escort tours for children aged 16 and under.

Table 19. Weekday other travel tours made by age category

Age band	Other travel tours						Total
	0	1	2	3	4	5	
under 5	*21*	*58*	*7*	*2*	*0*	*0*	*88*
	23.9 %	*65.9 %*	*8.0 %*	*2.3 %*	*0.0 %*	*0.0 %*	*100.0 %*
5–11	155	37	7	0	0	0	199
	77.9 %	18.6 %	3.5 %	0.0 %	0.0 %	0.0 %	100.0 %
12–14	54	23	2	0	0	0	79
	68.4 %	29.1 %	2.5 %	0.0 %	0.0 %	0.0 %	100.0 %
15–16	60	16	1	1	0	0	78
	76.9 %	20.5 %	1.3 %	1.3 %	0.0 %	0.0 %	100.0 %
17–20	93	33	2	2	1	0	131
	71.0 %	25.2 %	1.5 %	1.5 %	0.8 %	0.0 %	100.0 %
21–24	84	26	4	0	0	0	114
	73.7 %	22.8 %	3.5 %	0.0 %	0.0 %	0.0 %	100.0 %
25–30	113	40	3	0	0	0	156
	72.4 %	25.6 %	1.9 %	0.0 %	0.0 %	0.0 %	100.0 %
31–34	76	25	4	1	0	0	106
	71.7 %	23.6 %	3.8 %	0.9 %	0.0 %	0.0 %	100.0 %
35–39	98	38	7	0	0	0	143
	68.5 %	26.6 %	4.9 %	0.0 %	0.0 %	0.0 %	100.0 %
40–44	159	36	5	2	0	0	202
	78.7 %	17.8 %	2.5 %	1.0 %	0.0 %	0.0 %	100.0 %
45–49	133	42	11	1	0	0	187
	71.1 %	22.5 %	5.9 %	0.5 %	0.0 %	0.0 %	100.0 %
50–54	142	39	13	0	1	1	196
	72.4 %	19.9 %	6.6 %	0.0 %	0.5 %	0.5 %	100.0 %
55–59	142	39	10	0	0	0	191
	74.3 %	20.4 %	5.2 %	0.0 %	0.0 %	0.0 %	100.0 %
60–64	103	49	11	4	1	0	168
	61.3 %	29.2 %	6.5 %	2.4 %	0.6 %	0.0 %	100.0 %
65 and above	341	159	52	10	3	0	565
	60.4 %	28.1 %	9.2 %	1.8 %	0.5 %	0.0 %	100.0 %
Total	1,774	660	139	23	6	1	2,603
	68.2%	25.4 %	5.3 %	0.9 %	0.2 %	0.0 %	100.0 %

Other travel tours are observed by all age groups and the other travel tour frequency model has therefore been estimated from the full sample.

The final other travel frequency estimation sample is summarised in Table 20.

Table 20. Other travel tours made by weekday for all age groups

Tours	Count	Per cent
0	1,774	68.2 %
1	660	25.4 %
2	139	5.3 %
3	23	0.9 %
4	6	0.2 %
5	1	0.0 %
Total	2,603	100.0 %

The average other travel tour frequency rate is 0.396 tours per average weekday in school term time. The percentage of the population making two or more tours (5.3 per cent) is higher than all of the other HB purposes, and therefore there are more data available for the identification of socio-economic effects in the stop/go model. However, it is noted that no significant socio-economic effects were identified in the stop/go model but only in the 0/1+ model, as shown below.

3.8.2. Model results

The other travel frequency model results are presented in Table 21.

Table 21. Other travel frequency model results

Parameter name	Sub-model	Parameter		Definition
		estimate	t-ratio	
NoTour	0/1+	1.149	9.3	Constant to ensure overall fraction of individuals making at least one tour for other purposes is replicated
AgeIt13	0/1+	-1.272	-8.0	A child under the age of 13 is more likely to make a tour for other purposes than individuals in other age groups
licence	0/1+	-0.710	-6.2	Licence holders are more likely to make a tour for other purposes than non-licence holders
max1car	0/1+	0.389	4.2	Individuals from households with at most one car are less likely to make a tour for other purposes than individuals from households with more than one car
FTwork	0/1+	0.570	4.6	Full-time workers are less likely to make a tour for other purposes than part-time workers, those looking for jobs, children and university or college students
retired	0/1+	-0.630	-5.0	Retired persons are more likely to make a tour for other purposes than part-time workers, those looking for jobs, children and university or college students, but less likely than those with home duties
athome	0/1+	-0.815	-4.1	Individuals with home duties are more likely to make a tour for other purposes than part-time workers, those looking for jobs, children and university or college students
stop	stop/go	1.274	17.4	Constant to ensure observed rate of multiple tour-making is replicated

Employment status terms have been identified in the 0/1+ model. These indicate that retired persons or individuals with home duties are more likely to make other tours and the overall trip rate is lowest for those in full-time employment. Car accessibility parameters are also relevant, with licence holders more likely to make tours than non-licence holders, while individuals in households with at most one car are less likely to make tours than those in multi-car households.

4. Non-home-based frequency models

This chapter presents the frequency models for the six NHB purposes represented in the South East Wales Transport Model. As detailed in Section 2.2.2, NHB travel is identified once the HB tours have been determined. In the model application, NHB travel is forecast as a function of HB travel; specifically, the number of NHB tours is calculated as a function of the number of HB tours arriving in each PD zone. Therefore the NHB frequency models have been estimated from the samples of HB tours for which the NHB travel can occur.

Table 22 illustrates the relationship between the HB and NHB travel purposes; this follows from the way in which the purpose hierarchies are defined.

Table 22. Relationship between HB and NHB travel purposes

HB purposes	Related NHB purposes
commute home–business	work–work tours work–other tours work–work detours work–other detours
home–primary education home–secondary education home–tertiary education home–shopping home–escort home–other travel	other–other tours other–other detours

Note that 'home–other' travel is defined as all HB travel that is not made for commute, business, education, shopping or escort purposes, subject to the exceptions specified for each of these in Chapter 3, whereas for NHB 'other' travel means all travel that is not work-related.

For the HB tours, only weekdays during school term-time were included in the analysis. For the NHB analysis, since education-based tours were not considered separately, it was possible to include weekday tours made during the school holidays to increase the available sample size.

4.1. Work–work tours

4.1.1. Estimation sample

The work–work tour frequency model predicts the number of full tours made from work-related PDs to work-related SDs. Work-related PDs may be either work or EB, whereas the SDs can only be EB because only one main workplace is considered during the tour building, and if that workplace was visited during a trip chain it would form the PD of the tour.

Table 23 summarises the observed frequencies of work–work tour-making.

Table 23. Work-related PD-based tours made per full work-related HB tour

Tours	Count	Per cent
0	1,075	98.4 %
1	16	1.5 %
2	1	0.1 %
Total	1,092	100.0 %

The mean tour rate is just 0.016 work-related tours made per work-related HB tour. Only one individual made more than one PD-based tour in the course of a single HB tour, so there are very few data on multiple tour-making.

4.1.2. Model results

The results from the work–work frequency model are presented in Table 24.

Table 24. Work–work tour frequency model parameters

Parameter name	Sub-model	Parameter		Definition
		estimate	t-ratio	
NoTour	0/1+	-1.459	-2.2	Constant to ensure overall fraction of individuals making work–work tours is replicated
HB_bike	0/1+	4.292	16.0	Individuals who cycle on their HB tour are more likely to make PD-based work tours
stop	stop/go	2.833	2.8	Constant to ensure overall fraction of individuals making multiple work–work tours is replicated

The large positive constants on the zero tours and stop alternatives reflect the fact that most individuals make zero tours, and most of those who do make one tour do not make any further tours.

The 'HB_bike' parameter may be explained by individuals cycling to work then having their cycle available to them, which then facilitates their making more work–work tours.

4.2. Work–other tours

4.2.1. Estimation sample

The work–other tour model predicts the number of full tours made from work-related PDs to other (not work-related) SDs. Non-work-related SDs may be visited for education, shopping, escort or other travel purposes.

The estimation sample for the work–other tour frequency model is the sample of full work-related HB tours, which includes commute and home–business tours. Table 25 shows the number of other PD-based tours made per full work-related HB tour.

Table 25. Other PD-based tours made per full work-related HB tour

Tours	Count	Per cent
0	1,051	96.2 %
1	41	3.8 %
Total	1,092	100.0 %

The mean tour frequency rate is just 0.038 other tours per full work-related HB tour. No individual made two work-related tours during a single HB tour, so there are no data on multiple tour-making.

4.2.2. Model results

Table 26 presents the work–other tour frequency model results.

Table 26. Work–other tour frequency model results

Parameter name	Sub-model	Parameter		Definition
		estimate	t-ratio	
NoTour	0/1+	3.481	19.1	Constant to ensure overall fraction of individuals making work–work tours is replicated
HB_bike	0/1+	-1.999	5.1	Individuals who cycle on their HB tour are more likely to make PD-based work tours
Stop	stop/go	14.200	0.1	Constant to ensure overall fraction of individuals making multiple work–work tours is replicated

As per the work–work model, the 'HB_bike' parameter may be explained by individuals cycling to work and then having their cycle available to them which then facilitates them to make more work-based tours.

The large negative constant on the stop alternative reflects the fact that no multiple tour-making is observed in the data. The constants together ensure that the overall tour-making rate observed in the sample of 0.038 is replicated.

4.3. Other–other tours

4.3.1. Estimation sample

The other–other tour model predicts the number of full tours made from other (not work-related) PDs to other (not work-related) SDs. Non-work-related PDs and SDs may be visited for education, shopping, escort or other travel purposes.

The estimation sample for the other–other tour frequency model is the sample of full non-work-related HB tours, which includes home–primary education, home–secondary education, home–tertiary education, home–shopping, home–escort and home–other travel tours (Table 27).

Table 27. Other tours made by full other HB tour

Tours	Count	Per cent
0	2,667	99.1 %
1	25	0.9 %
Total	2,692	100.0 %

The mean tour frequency rate is just 0.009 other tours per full other HB tour, even lower than the tour rates for work–work and work–other models. Again, no individual made more than one tour, so there are no data on multiple tour-making; the stop/go sub-model contains just a constant to ensure that the models replicate the overall tour rate observed in the sample.

4.3.2. Model results

The results from the other–other tour frequency model are presented in Table 28.

Table 28. Other–other tour frequency model results

Parameter name	Sub-model	Parameter		Definition
		estimate	t-ratio	
NoTour	0/1+	4.670	23.2	Constant to ensure overall fraction of individuals making work–work tours is replicated
Stop	stop/go	13.203	0.1	Constant to ensure overall fraction of individuals making multiple work–work tours is replicated

It was not possible to identify any significant socio-economic effects or HB tour mode constants in the other–other model, and therefore the only parameters in the model are the constants.

4.4. Work–work detours

4.4.1. Estimation sample

The work–work detour models predict the number of detours made during work-related tours to work-related SDs. Work-related PDs may be either work or EB,[8] whereas the SDs can only be EB because only one main workplace is considered during the tour building, and if that workplace was visited during a trip chain it would form the PD of the tour.

The estimation sample for the work–work detour frequency model is the sample of full work-related HB tours, which includes commute and home–business tours. The number and percentage of work-related detours made per full work-related HB tour is shown in Table 29.

Table 29. Work-related detours made per full work-related HB tour

	Outward legs of HB tours		Return legs of HB tours	
	Count	Per cent	Count	Per cent
no detour	1,058	96.9 %	1,044	95.6 %
detour(s)	34	3.1 %	48	4.4 %
Total	1,092	100.0 %	1,092	100.0 %

The detour frequency rate on outward tour legs is 0.03 detours per HB tour, whereas on return tour legs the frequency rate is significantly higher at 0.04 detours per HB tour. Separate models have been developed for detours made during the outward and return legs of HB tours, firstly because of the difference in detour frequency rates and, secondly, because different variables may explain the detours on the two legs. As per the discussion in Section 2.2.2, only one detour per tour leg is considered in the modelling and therefore the detour models represent the binary choice between no detour and detour for a given HB tour leg.

Detour frequency rates are relatively low overall, so most individuals make no detours to work-related destinations on the outward or return legs of work-related HB tours.

4.4.2. Model results

The results from the work–work detour models are presented in Table 30.

[8] Both work and employer's business are considered as work PDs in the NHB frequency models. Separate models have been developed for HB tours to these PD types (see Sections 3.1 and 3.2).

Table 30. Work–work detour frequency model results

Parameter	HB tour direction	Parameter estimate	Parameter t-ratio	Definition
none_O	outbound	4.487	10.9	Constant to ensure overall fraction of observed outward work-related detours is replicated
male_O	outbound	-1.555	-3.4	Males are more likely to make work-related detours on outward tour legs than females
cartrain_R	return	3.772	10.6	Individuals who travel by train or drive a car on their HB tour are more likely to make a work-related detour on their return tour leg to a work-related destination
none_R	return	-0.916	-2.3	Constant to ensure overall fraction of return work-related detours observed is replicated

The outward detour rate for males was 0.051 while for females it was 0.011. Hence men are much more likely to make work-related detours on the way to a workplace. Commuters who drive or take the train have a return detour rate of 0.054 compared with 0.022 for users of other modes.

4.5. Work–other detours

4.5.1. Estimation sample

The work–other detour models predict the number of detours made during work-related tours to non-work-related SDs. Work-related PDs may be either work or employer's business, whereas non-work-related SDs may be visited for education, shopping, escort or other travel purposes.

The estimation sample for the work–other detour frequency model is the sample of full work-related HB tours, which includes commute and home–business tours. Other detours are detours made for non-work-related purposes, and therefore include escort detours made during the outward or return legs of commute tours. Table 31 shows the number and percentage of non-work-related detours made per full work-related HB tour.

Table 31. Non work-related detours made per full work-related HB tour

	Outward legs of HB tours		Return legs of HB tours	
	Count	Per cent	Count	Per cent
no detour	1,001	91.7 %	962	88.1 %
detour(s)	91	8.3 %	130	11.9 %
Total	1,092	100.0 %	1,092	100.0 %

The detour frequency rates are 0.083 per outward HB tour leg, and 0.119 per return tour leg. Thus detour rates to other locations are significantly higher than detour rates to work-related locations. Return-leg tour detour rates are somewhat higher than outward-leg detour rates, and therefore separate detour

frequency models have been estimated for outward and return-leg detours. Only one detour per tour leg is considered in the modelling.

4.5.2. Model results

Results from the work–other detour models are presented in Table 32.

Table 32. Work–other detour frequency model results

Parameter name	HB tour direction	Parameter		Definition
		estimate	t-ratio	
none_O	outward	3.643	12.3	Constant to ensure overall fraction of observed outward work–other detours is replicated
cardriv_O	outward	-1.333	-4.5	Individuals who drive a car for their HB work tour are more likely to make work-other detours on outward tour legs than users of other modes
age31_40_O	outward	-0.648	-2.6	Individuals in the 31–40 age group are more likely to make work–other outward leg detours than other age groups
PTtime_O	outward	-0.843	-3.4	Part-time workers are more likely to make work–other detours on outward tour legs than other status groups
HHcarsge3_O	outward	1.048	2.4	Individuals in households with 3+ cars make fewer other outward-leg detours than individuals in households with fewer cars
none_R	return	2.474	13.2	Constant to ensure overall observed fraction of return work–other detours is replicated
cardriv_R	return	-0.682	-3.2	Individuals who drive a car for their HB work tour are more likely to make work–other detours on return tour legs than users of other modes

Car drivers are more likely to make detours for other purposes on both the outward and return leg of an HB work tour. For example, the outward detour rate is 0.110 for car drivers and 0.038 for other modes. These effects are captured using the cardriv_O and cardriv_R parameters.

Part-time workers and those in the 31–40 age group are also more likely to make outward detours. This may be explained by escort trips, as these are included in other purposes for NHB detours.

Households with three or more cars make substantially fewer detours (0.022) than other households (0.091).

4.6. Other–other detours

4.6.1. Estimation sample

The other–other detour models predict the number of detours made during non-work-related tours to non-work-related SDs. Non-work-related PDs and SDs may be visited for education, shopping, escort or other travel purposes. Table 33 summarises the number of non-work related detours made per non-work-related HB tour.

Table 33. Non-work-related detours made per non-work-related HB tour

	Outward legs of HB tours		Return legs of HB tours	
	Count	Per cent	Count	Per cent
no detour	2,471	91.8 %	2,451	91.0 %
detour(s)	221	8.2 %	241	9.0 %
Total	2,692	100.0 %	2,692	100.0 %

Mean detour frequency rates are 0.082 during outward tour legs, and 0.090 during return tour legs. The detour frequency rate is slightly higher on the return tour legs, and therefore once again separate detour frequency models have been developed for outward and return-leg detours. Only one detour per tour leg is considered in the modelling.

4.6.2. Model results

Results from the detour models are presented in Table 34.

Table 34. Other–other detour frequency model parameters

Parameter name	HB tour direction	Parameter		Definition
		estimate	t-ratio	
none_O	outward	2.224	27.8	Constant to ensure overall fraction of observed outward other–other detours is replicated
walk_O	outward	1.354	6.3	Individuals who walk for their HB other tour are less likely to make other–other detours on outward tour legs than users of other modes
athome_O	outward	-0.870	-4.1	Individuals with duties at home are more likely to make other–other detours on outward tour legs than other status groups
none_R	return	3.163	20.9	Constant to ensure overall fraction of observed return other–other detours is replicated
AgeIt17_R	return	-0.518	-3.4	Individuals aged under 17 years are more likely to make other–other return leg detours than other age groups
car_R	return	-1.053	-6.6	Individuals who travel by car on their HB work tour are more likely to make other–other detours on return tour legs than users of other modes

Individuals with duties at home are more likely to make outward detours on HB tours made for non-work-related purposes, with a detour rate of 0.144 compared with 0.076 for other status groups. On the return leg, car users (drivers and passengers) are likely to make a detour, as are individuals aged 16 years or under. Again, these effects are plausible for weekday trips that include escort and education purposes.

5. Adjustments to work-related travel frequency

5.1. Comparison of daily trip rates

Concerns were raised by WG about the representativeness of the South East Wales household interview (HI) data travel frequency rates for work-related purposes, i.e. commute and EB travel purposes.

To investigate these concerns, the disaggregate frequency models documented in Chapter 3 were applied to the expanded base year population of South East Wales and then the overall predicted base year frequency rates were calculated for each travel purpose. The processes used to generate the expanded base populations are not described here, but are documented separately in the model implementation report.

It should be noted that the frequency model estimations documented in Chapter 3 use the *unweighted* HI data, and so in cases where the expanded base year population has a different distribution over segments that will give rise to differences between the unweighted HI trip rates and those calculated for the expanded base year population. For example, if a commute frequency model distinguishes between full-time and part-time workers, with the lower tour frequency rate for the latter group, and the HI data has a higher fraction of part-time workers than the expanded base population, then we would expect the HI frequency rate to be lower than that for the expanded base population. The expanded base population is generated to be representative of the actual population and as such the average tour rate predicted using the expanded base population is the best prediction of overall tour rates in the base year.

Another issue for this comparison is that, as Section 3.2 demonstrates, the volume of EB travel recorded in the HI data was too low to allow a disaggregate frequency model to be estimated. This issue is discussed further below.

The South East Wales tour rates that are predicted for the 2015 base year have been compared to against two other sources:

- The National Trip End Model (NTEM)
- The most recent PRISM Household Interview (HI) data.

It is emphasized that the NTEM trip rates are predictions from a national trip end model and therefore are *not* observed data. That said, NTEM is a trusted source for trip rates and is the fallback option when there are not sufficient data to allow development of local frequency models. The comparison to the PRISM HI data provides a comparison to a recent dataset that uses exactly the same tour-based approach to the South East Wales frequency models documented in Chapter 3. The PRISM data have also played a vital role in the development of mode-destination models for this study.

For home-based trips the NTEM productions were first doubled to convert them into trips. The HB trips were then converted into trip rates per person by dividing by the total TEMPRO population for South East Wales.[9]

Table 35 presents a comparison of the HB trip rates. As the samples of EB trips in the South East Wales HI data were too low to allow a model to be developed, no trip frequency rates are predicted for this purpose.

Table 35. HB trip rate comparison prior to adjustment (trips/day)

Purpose	SEWTM 2015 predicted	NTEM 7.1 South East Wales		PRISM West Midlands HI data (2009–2012)	
		rate	diff.	rate	diff.
commute	0.74	0.51	45.5%	0.62	6.1%
employer's business	n/a	0.06	n/a	0.08	11.3%
education	0.40	0.39	2.0%	0.39	1.6%
shopping	0.38	0.48	-19.9%	0.30	28.5%
other travel	1.03	0.74	39.8%	0.64	60.5%
Total	2.55	2.18	17.3%	2.03	25.9%

It can be seen from Table 35 that the predicted commute trip frequency rate is significantly higher than the NTEM 7.1 rate. The difference compared to NTEM 7.1 is consistent with the concern that some EB travel in the South East Wales HI was miscoded as commuting, as the impact of this would be for the commute frequency model to over-predict the true commute tour frequency rate.

For education, there is a good correspondence between the South East Wales predictions, NTEM and the PRISM HI. Finally, the South East Wales predictions show lower frequency rates for shopping but higher rates for other travel.

Table 36 presents the same set of comparisons for NHB travel. It is noted that NTEM uses a NHB work purpose, whereas in the RAND Europe tour-based approach used for PRISM and the South East Wales modelling only NHB business and NHB other purposes are distinguished. Section 2.2.2 provides more detail.

[9] The TEMPRO areas taken to define South East Wales are Blaenau Gwent, Bridgend, Caerphilly, Cardiff, Merthyr Tydfil, Monmouthshire, Newport, Rhondda Cynon Taf, The Vale of Glamorgan, Torfaen and Neath Port Talbot.

Table 36. NHB trip rate comparison (trips/day)

Purpose	SEWTM 2015 predicted	NTEM 7.1 South East Wales		PRISM West Midlands HI data (2009–2012)	
		rate	diff.	rate	diff.
NHB work	0.034	0.062	-76.9%	0.017	105.2%
NHB business		0.086			
NHB other	0.244	0.405	-39.7%	0.146	67.0%
Total	0.278	0.553	-49.7%	0.163	70.9%

It can be seen that the overall South East Wales NHB trip rates are significantly lower than those predicted in NTEM 7.1. However, NTEM identifies NHB travel differently to the tour-based approach used in NTEM, and the South East Wales NHB trip rates are substantially higher than those observed in the PRISM HI data.

Given the difficulties in directly comparing between NTEM and trip rates derived from the tour-based approach used in the SEWTM, it was decided to compare total trip rates for work-related purposes, i.e. commute and business combined. This total trip rate comparison, i.e. without separation into HB and NHB categories, is presented in Table 37.

Table 37. Total trip rate comparison

Purpose	SEWTM 2015 predicted	NTEM 7.1, SEW	
		rate	diff.
work-related	0.69	0.72	-4.7%
other purposes	2.05	2.01	2.3%
Total	2.74	2.73	0.4%

At this aggregate level the SEWTM trip rates validate well against the NTEM 71 predictions for both work-related and non-work-related travel, and remarkably well at the total trip level. This result gives confidence that the South East Wales HI has captured *total trip making* accurately. It was therefore agreed with WG that adjustments would be applied to the commute and home–business trip rates to give a more representative split between these two purposes, but that no adjustments would be made to *overall* HB or NHB trip rates. The approach used to make these adjustments is documented in Section 5.2.

5.2. Adjustments to travel frequency models

Table 38 shows the percentage of work-related travel that is home–business for the South East Wales predictions from NTEM 7.1, the South East Wales NTS data, and the PRISM West Midlands HI data.

Table 38. Percentage of work-related HB travel that is home–business

Source	Years	Coverage	Business percentage
NTEM 7.1	2015	South East Wales	10.8%
NTS	2007–2012	South East Wales	11.3%
PRISM	2009–2012	West Midlands	13.2%

The fraction of work-related HB travel for business lies in the 10–13 per cent range. Given that the NTEM 7.1 data is for 2015 and for South East Wales, it was decided to adjust the SEWTM work-related frequency rates so that the percentage of work-related travel that is home–business is exactly 10.8 per cent. This was done because the evidence is consistent with WG's belief that some EB trips had been miscoded as commuting in the survey; i.e. while the combined commute plus EB trip rate in the survey is consistent with other sources the split between commute and EB is not.

Table 39 summarises the HB trip rates after adjusting the work-related travel frequency rates. Relative to Table 35 the only SEWTM values that have changed are the commute and home–business frequency rates highlighted in red; as the total work-related frequency rate is unchanged the overall frequency rate is also unchanged.

Table 39. HB trip rate comparison after adjustment (trips/day)

Purpose	SEWTM 2015 predicted	NTEM 7.1		PRISM HI data (2009–2012)	
		rate	diff.	rate	diff.
commute	0.66	0.51	29.7%	0.62	7.7%
employer's business	0.08	0.06	29.7%	0.08	-0.7%
education	0.40	0.39	2.1%	0.39	1.6%
shopping	0.38	0.47	-19.7%	0.30	28.5%
other travel	1.03	0.74	40.0%	0.64	60.5%
Total	2.55	2.18	17.2%	2.03	25.9%

Following the adjustment, the SEWTM commute and EB rates are both 30 per cent higher than those in NTEM 7.1, which follows from the fact that the *proportion* of commute and EB rates that is comprised of

EB has been adjusted to be equal to NTEM 7.1. It is noted that after adjustment the EB frequency rate closely matches that observed in the PRISM HI data, which uses the same definitions of HB tours and NHB travel as the SEWTM frequency models.

No adjustments have been applied to the SEWTM NHB frequency rates, and so the SEWTM NHB trip rates presented in Table 36 are the final values. Similarly, as the total work-related frequency rate was not altered in the adjustment, the SEWTM total trip rates presented in Table 37 are also the final values.

6. Summary

In this report we have documented the development of frequency models for HB tours and for work-related and non-work-related NHB tours and detours. The data used to estimate the models were taken from HIs, which covered the entire project area of Cardiff and Penarth, as well as Caerphilly, Pontypridd and Barry. The data collection methodology is not described here and only the frequency model estimation and results are reported.

Frequency models have been estimated for seven HB tour purposes: commute, primary education, secondary education, tertiary education, escort, shopping and other. Few tours for EB travel were recorded in the HIs and it was therefore not possible to estimate an HB EB model from the survey data for this purpose. The number of EB tours relative to commute tours recorded in the survey was found to be low compared to those reported in the NTS data and in the PRISM model, both of which have much larger sample sizes. Given that the PRISM model will form the basis of the mode-destination part of the SEWTM, the PRISM frequency model will also be adopted for the HB EB tours, with an adjustment applied to ensure the balance of commute and home–business travel frequency is consistent with NTEM v7.1. For NHB tours and detours, commute and EB tours were combined.

Socio-economic characteristics have been found to be significant in explaining variation in tour-making for different travel purposes. These depend on the tour purpose and type but include employment status, age, household size and car availability. However, for some tour types, the relatively small sample sizes may have affected the socio-economic effects that have been possible to identify. In particular, few effects were determined for NHB PD tours and it was not possible to identify changes in the likelihood of tour-making for different purposes with age. The approach to estimating frequency models for secondary and tertiary education may also need revisiting should there be any change in the school leaving age in the future.

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