4. DEMAND MODEL CALIBRATION

4.1 GENERATION MODEL

4.1.1 Preparation and Realisation of the RP Survey

The Household and Household Travel Surveys were undertaken over the whole of Greater Nottingham and the survey is described in detail in the Survey Report.

A total of 3250 households sampled by the method of firsting from the electoral roll were approached. A basic sample of 2000 households covered the Greater Nottingham area with enhanced and reserve samples drawn from the south western sector including the A453 corridor. Some 890 households provided valid returns which has provided an adequate database for the transportation model. Information collected included household characteristics, personal travel characteristics and 24 hour travel diaries for all members of the household aged 5 or more.

4.1.2 Analysis of the RP Survey

4.1.2.1 Behavioural Groups

Residents of the modelled area have been allocated to 11 behaviourally homogenous person groups (BHPG). These groups are compatible with those defined for the DTLR National Trip End Model (NTEM) planning input data based on the three criteria of

- Age
- Gender
- Occupation

Two additional commuter groups have also been defined in order to analyse trips from outside the modelled area. These are economically active and inactive commuters. This allocation is based mainly on using the parameters

- Trip destination
- Occupation

In this study a person is defined as a commuter if he or she has made at least one trip crossing the Inner Modelling Area boundary.

Table 4.1 gives a detailed description of the segmentation of the population into the 13 different behaviourally homogenous person groups. Figure 4.1 shows the comparison of group distribution between the results of the household survey and the NTEM planning data for the inner model area. This comparison is satisfactory for modelling purposes. Figure 4.2 illustrates the number of trips per day for the defined person groups, the so-called mobility rates, as they have been found from the household survey.

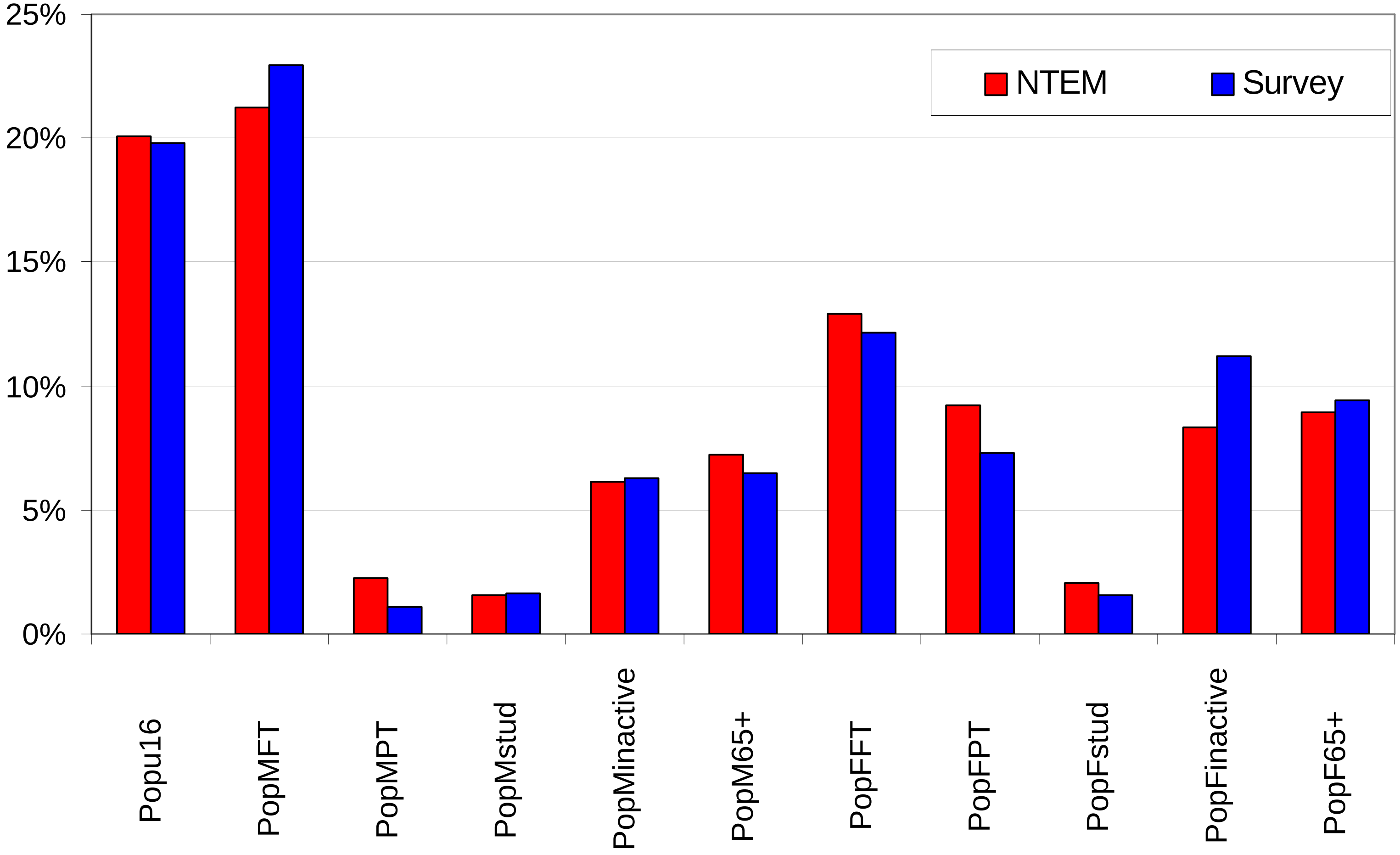

Figure 4.1 Population Segmentation

Table 4.1: Definition of Behaviourally Homogenous Person Groups

No.	Abbreviation	Description	Definition in the household survey
1	PopU16	Population under 16	Age < 16
2	PopMFT	Population – Males – Employed Full Time	Males, full time employed, military personnel
3	PopMPT	Population – Males – Employed Part Time	Males, part time employed
4	PopMStud	Population – Males – Student	Males, age >= 16, in school, college/university or training/Apprenticeship
5	PopMinactive	Population – Males – Economically Inactive	Males, unemployed, househusband, retired below 65
6	PopM65+	Population – Males – Aged 65 or over	Males, age >= 65
7	PopFFT	Population – Females - Employed Full Time	Females, full time employed, military personnel
8	PopFPT	Population – Females - Employed Part Time	Females, part time employed
9	PopFStud	Population – Females – Student	Females, age >= 16, in school, college/university or training/Apprenticeship
10	PopFinactive	Population – Females – Economically Inactive	Females, unemployed, housewife, retired below 65
11	PopF65+	Population – Females - Aged 65 or over	Females, age >= 65
12	Ecomm	Economically active commuters	Minimum one trip outside the inner modelled area, full-time, part-time employed or military personnel
13	NEComm	Economically inactive commuters	Minimum one trip outside the inner modelled area, unemployed or housewife/husband

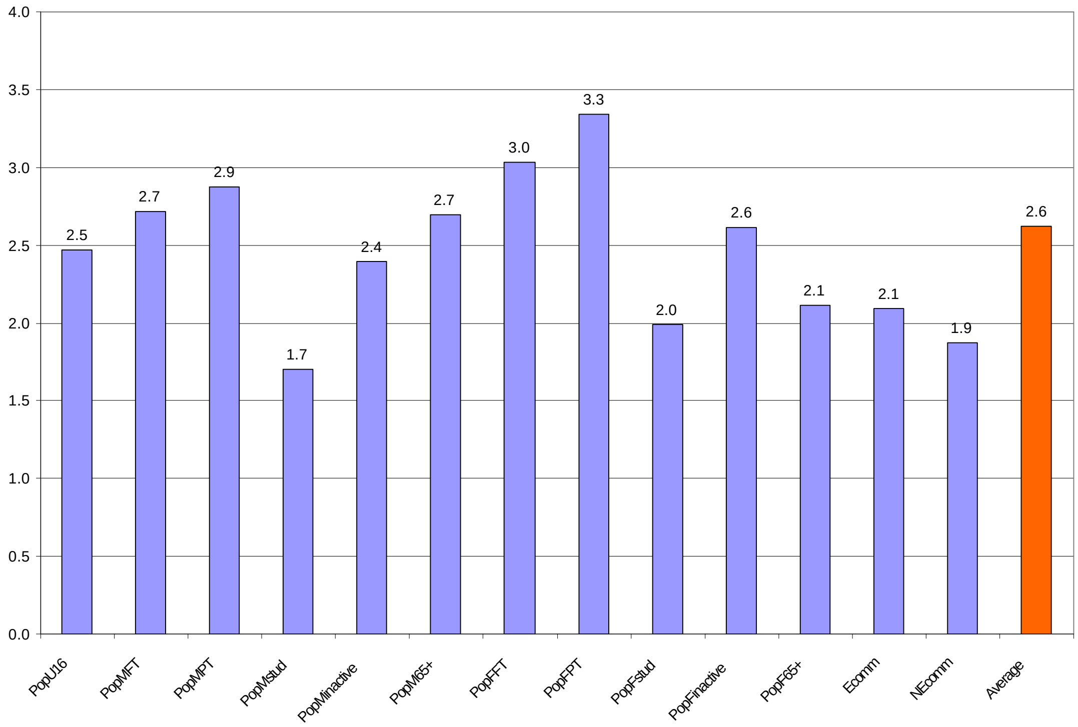

Figure 4.2 : Mobility rates (number of trips per day)

4.1.2.2 Activity Chain Distribution by Behavioural Homogenous Person Groups

The Household Survey questionnaire collected information for eight categories of trip purposes as follows:

- Workplace (normal place of work)
- Employers business
- Education/School
- Shopping/ personal business
- Leisure
- Take/Fetch someone
- Home
- Other

These trip purposes are grouped together to define trip activity. Table 4.2 describes briefly the criteria used.

Table 4.2: Activities in the demand model

Abbreviation	Activity	Description
H	Home	Home
J	Job	Workplace
P	Education	Primary school
C	Education	Secondary school
U	Education	College, university, apprenticeship/training
D	Shopping	Shopping of daily goods
S	Shopping	Shopping of long term goods
L	Leisure	Library, visiting friends/parents/someone, recreation, church.
F	Take/fetch	Take or fetch somebody, service

The activity „Employer's business“ from the household survey does not appear on this list for the demand model, because it constitutes part of the separate demand segment for Commercial Traffic.

Figure 4.3 shows the shares of relevant activities for the 13 person groups found from the household survey.

Activity chains describe the order of different activities during a person's day. Behavioural group specific activity chains are prepared from the household survey assuming that every chain begins from home and also ends at home. An example of these activity chains and the frequency of trips recorded for males in full time employment and females in part time employment during the household interview survey is given in Table 4.3.

The table only includes those activity chains with a frequency of more than 0.5%

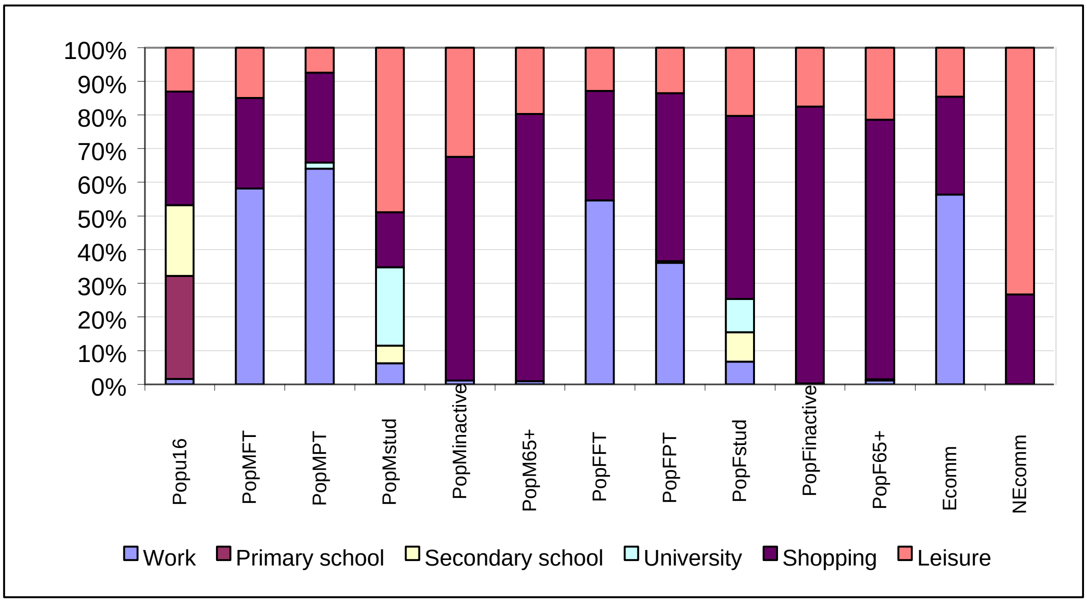

Figure 4.3 : Activities by person group

Table 4.3: Activity chains and frequency – Pop MFT and Pop FPT

Activity Chain	Frequency [%]	
	PopMFT	PopFPT
HDH	8.15	23.38
HSH	3.01	8.65
HFH	8.67	18.28
HJH	55.53	44.26
HLH	11.41	19.17
HDDH	1.45	2.79
HSSH	0.53	1.03
HDJH	0.00	1.04
HFDH	0.42	0.66
HFFH	0.85	0.67
HFJH	1.60	2.25
HFLH	1.74	1.92
HJDH	1.42	1.74
HJSH	0.53	0.65
HJFH	0.84	3.49
HJJH	3.08	0.62
HLJH	0.08	0.53
HLLH	3.37	0.42

Activity Chain	**Frequency [%]**	
	PopMFT	PopFPT
HDDDH	1.00	1.26
HDDFH	0.00	1.52
HSSFH	0.00	0.56
HFFFH	0.00	0.66
HFFJH	0.08	0.90
HFJDH	0.00	2.25
HFJFH	1.29	1.30
HFLFH	1.18	0.00
HJDDH	0.63	0.00
HJDJH	1.65	0.23
HJSJH	0.61	0.08
HLFFH	0.00	0.90
HLJDH	0.69	0.00
HLLLH	0.94	0.31

Figure 4.4 compares the total number of trips as derived from the household survey with data produced using the demand model (based on study planning data). This shows a very close correlation. The different temporal pattern for activities is illustrated for the example of trips from home to work and from work to home in Figure 4.5.

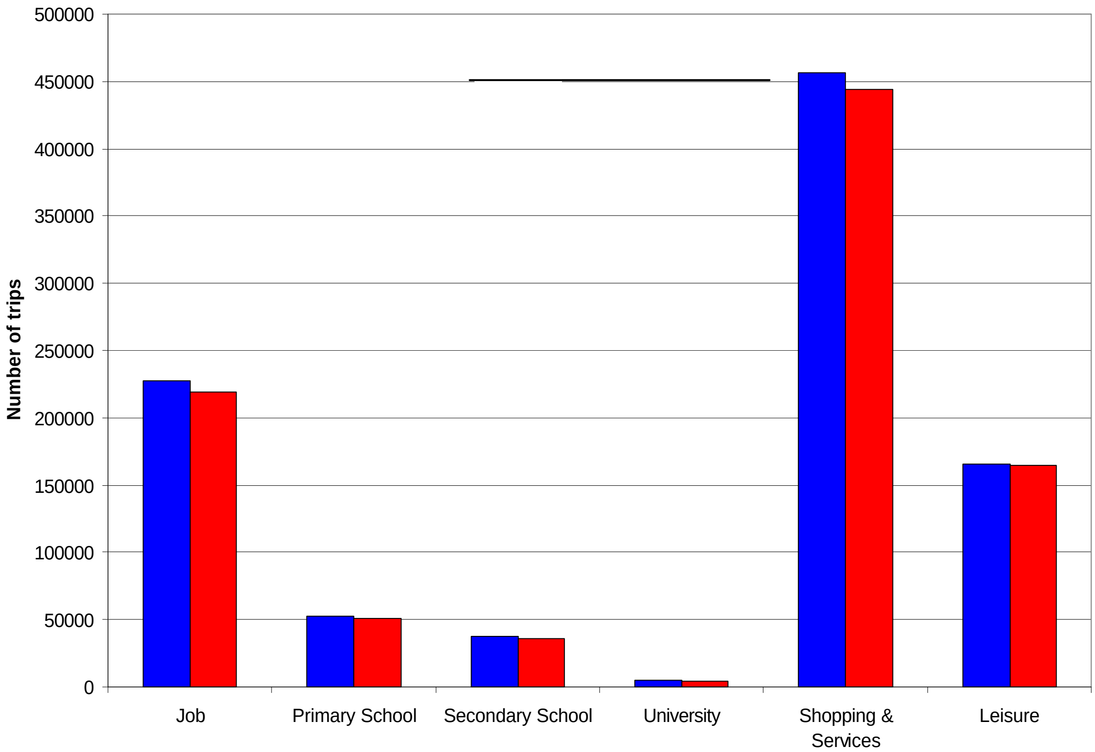

Figure 4.4 : Number of trips in the Study Area by Trip Purpose

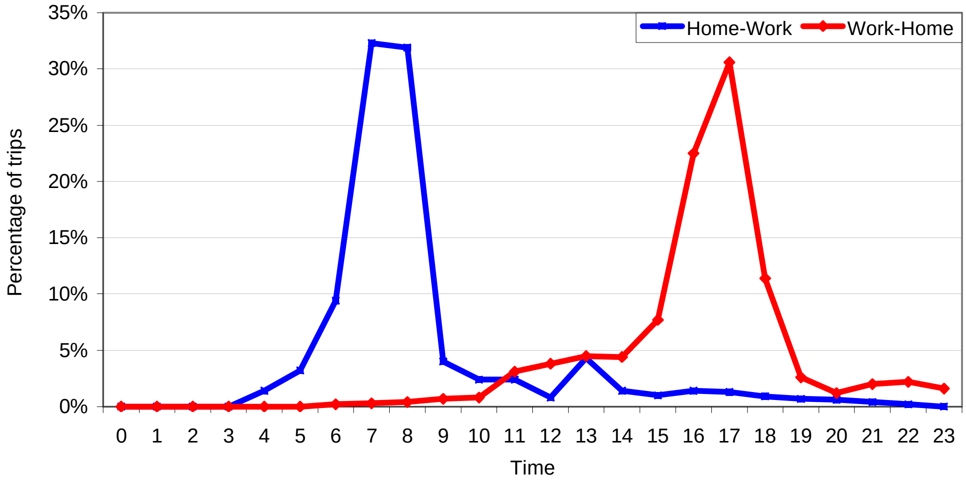

Figure 4.5 : Time pattern of activities (example)

4.1.2.3 Modal Split by Behavioural Homogenous Person Groups

Means of transport identified in the household survey are grouped together into the five major transport modes used in the demand model. Before an activity chain can be processed it has to be decided, if it belongs to a non-exchangeable transport mode or to an exchangeable one.

An exchangeable transport mode is one where the mode can be changed during the trip chain, for example foot where you can change to public transport if it is available.

A non-exchangeable mode is one such as car as driver, where once the journey has begun the same mode must be used for the whole trip chain otherwise the car would be stranded at a remote location. In the case of a non-exchangeable mode this choice holds for the whole chain, while exchangeable modes are estimated for every trip in the chain.

One special case is that of Park and Ride, where a special procedure has been developed to allow Park and Ride services to be modelled, which is outlined in section 4.3 of the report.

Table 4.4 illustrates the allocation to exchangeable modes for the A453 MMS.

Table 4.4: Transport Modes in the Demand Model

Type	Mode	Description
Exchangeable transport modes	Foot	Walking
	Car as passenger	
	Public transport	Bus (including school and work buses), Light and Heavy Rail (Central Trains, Midland Mainline), Taxi
Non-exchangeable transport modes	Car as driver	Car, LGV, OGV, Motorised bicycle
	Bicycle	Bicycle

Figure 4.6 shows the shares of the five major modes in comparison between the household survey and the trip end modal split predicted by the transportation model. The differences are small and demonstrate the recognition of local travel characteristics in the A453 MMS modelling process. Figure 4.7 illustrates the different mode preferences of the population segments as found from the demand model.

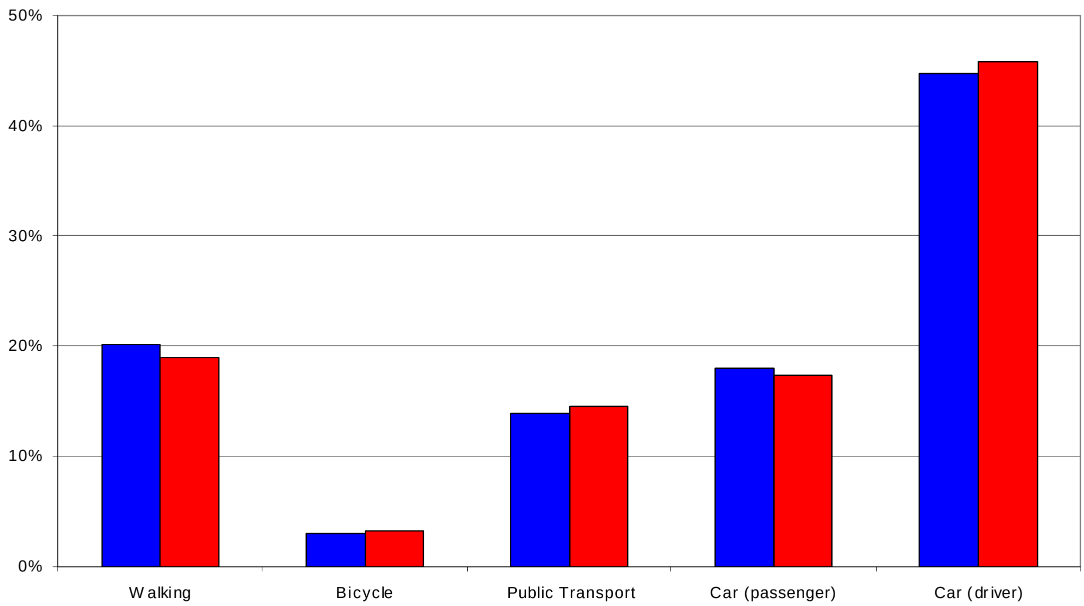

Figure 4.6 : Mode Shares, Household survey and Demand Model

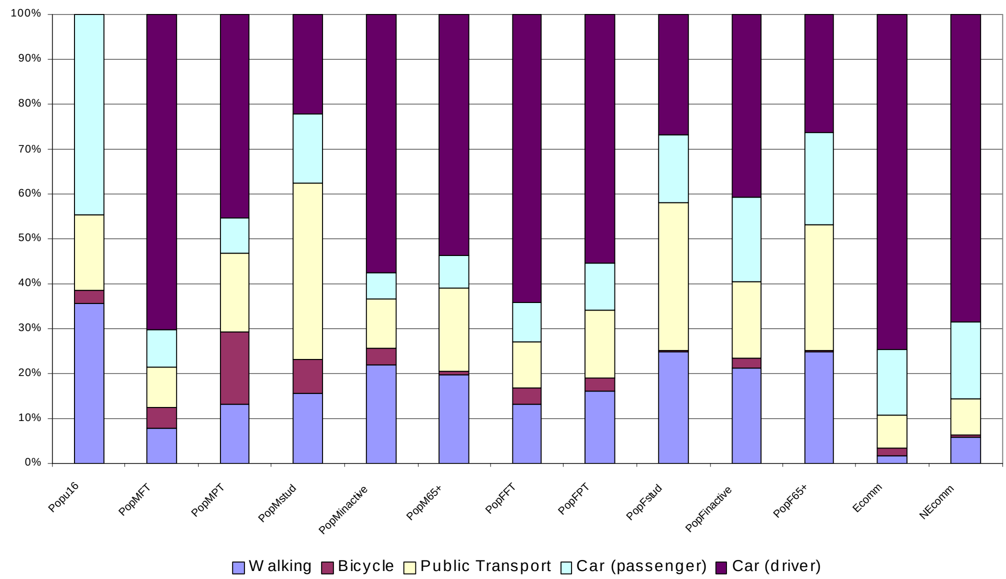

Figure 4.7 : Mode Shares for the Model Population Segments

4.1.2.4 OD-Matrices by Group and Purpose

The demand model is able to produce OD matrices for each of the defined modes, activities and population segments. Of particular importance for the further modelling are the matrices for the modes “Car“ and “Public Transport“.

4.1.3 Preparation and Realisation of the Stated Preference Survey

4.1.3.1 Concept

In addition to the household survey, which asked for actual behaviour – a so-called Revealed Preference (RP) study –, a second study was carried out in the form of two Stated Preference (SP) surveys. SP experiments present individuals with hypothetical travel scenarios and seek their preferences. These surveys can be individualised in a way, that alternatives to real journeys made by survey participants can be tested.

For this study two separate SP surveys based on the household survey have been carried out. One was asking for the decisions between Private and Public Transport, the second one dealt with preferences between Private transport and Park and Ride.

4.1.3.2 Preparation of the SP Data for Parameter Estimation

While the public transport survey was a standardised SP with general descriptions of trips, the P+R survey was carried out as a tailored study (situative study) based on travel reported in the household survey.

The obtained SP data were input and weighted according to the weighting of the RP data set. Weights were calculated on the basis of the number of cars per household, gender and geographical distribution of the respondents. In spite of the relatively small number of observations the weights showed a high representativity of the sample members.

Search time for a parking place is only included in the pairwise choice for private transport vs Park and Ride, because of the small sample size in the survey. In the Public transport users SP survey very few respondants had destinations where searching for a parking place was anticipated to be a significant consideration. The small sample size also limited the number of variables that could be estimated to eight. Therefore it was decided to use car park searching time in the Park and Ride survey instead of access time which would be zero or near to it in this case.

Persons, who chose only one mode across all choice tasks, were regarded as captives and have been removed from the estimation. The estimated parameters were allocated to the alternative modes as follows:

Table 4.5: Stated Preference Survey Attributes

Private Transport	**Public transport**
Journey time Costs (for parking)	Access Time Service frequency PuT Mode (Bus, LRT) Journey Time Number of transfers (0, 1, 2) Costs (PuT fare)

Private Transport	**Park + Ride**
Journey time Costs (for parking) Search time for parking place	Journey time (PrT + PuT) Costs (P+R and PuT fare) PuT Mode (Bus, LRT) Service frequency Number of transfers (0, 1, 2)

In the next step the attribute values were assigned to each data set containing the respondents' choices. Having done this each data set now comprised the household and the person number, the attribute values, the choice itself and some additional data. For example, after this procedure 2,187 data sets were available for the actual estimation of the park-and-ride SP model.

4.1.3.3 Utility Functions for Discrete Choice Modelling

The data from the SP surveys and from the trips reported (RP) have been analysed using the LIMDEP 7.0 software (Econometric Software, 1998) containing the NLOGIT procedure. It implements both simple multinomial (MNL) and nested logit (NL) structures.

The MNL model is based on the idea of utility maximisation, i.e. the choice observed reflects a reasoned judgement of the traveller about all available options. The general model form is

$$P_{jq} = \frac{e^{bV_{jq}}}{\sum_i e^{bV_{iq}}} ,$$

with b = 1 by definition. The systematic utility V_{jq} is a function of the attributes of alternative j for person q and of the socio-demographic variables describing person q. The parameters of the attributes and of the socio-demographic variables are estimated using the maximum likelihood approach. In this case, there are two alternatives, and V is a sum of terms consisting of products of estimated parameters and individual variables.

The analysis results are listed in Table 4.6. These co-efficients have been used for modelling P+R and reactions to changes in the public transport fares. An additional estimation revealed values of time with 0,03 GBP/min for Private Transport and 0,05 GBP/min for P+R.

Table 4.6: Stated Preference Model Estimation

Variable	Coefficient	Significance
Private Transport		
(Constant)	-0.2250	>54% (not sign.)
Journey Time	-0.0160	>99%
Costs (for parking)	-0.2773	>99%
Public Transport		
Access Time	0.0232	>87%
Service frequency	-0.0093	>99%
PuT Mode (Bus, LRT)	0.3743	>99%
Journey Time	-0.0198	>99%
Number of transfers (0, 1, 2)	-0.5315	>99%
Costs (PuT fare)	-0.5901	>98%
Private Transport		
(Constant)	-0.6788	>77%
Journey Time	-0.0219	>90%
Costs (for parking)	-0.8567	>99%
Search time for parking place	-0.0626	>99%
Park + Ride		
Journey time (PrT + PuT)	-0.0349	>99%
Costs (P+R and PuT fare)	-0.7662	>99%
PuT Mode	0.1724	>88%
Service frequency	-0.0495	>99%
Number of transfers (0, 1, 2)	-0.9240	>99%

A positive value for the variable PuT Mode portends preference of LRT over bus services. In general high absolute values of coefficients indicate their importance for the mode choice decision.

4.2 CALIBRATION OF THE DEMAND MODEL

4.2.1 Introduction

Having defined the determinants of travel demand from the behavioural and structural data as described above and also having established the integrated Public and Private Transport network model for the study area, the demand model can be composed by carrying out the following activities:

- **Preparation of the Public Transport supply quality matrix**.
  This matrix describes the quality of Public Transport connections between the zones in terms of service frequencies and the number of necessary transfers.
- **Preparation of additional parameters for trip distribution and mode choice.**
  These are amongst others access/egress times, initial waiting times in Public Transport, parking charges or additional values for particular travel modes (e.g. heavy rail).
- **Preparation of the mode specific general cost matrices for trip distribution.**
  This is an iterative task and has to be carried out repetitively for the private transport. The costs for trips with the car (i.e. journey times) depend on the flows in the network – which are unknown before an assignment and therefore have to be corrected with the results of an assignment results in an iterative process.
- **Calibration of the trip purpose and person group specific parameters for the deterrence function of the trip distribution gravity model**
- **Inclusion of the estimated parameters of the SP/RP model for mode choice**
- **Calibration of the modal split factors for the person groups**
- **Preparation of the VISEM project files**
  All data and references to external input files are composed in one control file.

Pedestrian and cycle movements are included in the demand model only. The trip assignment doesn't include any modelling of pedestrian and cycle movements. The only exception to this are the modelling of short pedestrian connections when transferring between adjacent public transport stops or stations or access times to the transport networks.

4.2.2 Parking in the City Centre

Parking charges play an important role in the mode choice process. Extensive parking management and control is already in place in Nottingham City centre. Therefore the transport model needs to reflect the new more extensive parking charges within it.

Publicly available parking facilities in the city centre comprise

- Multi-storey car parks. 8400 spaces at 14 locations with different prices
- Surface car parks. 700 spaces at 9 locations
- On street parking. Over 2000 spaces, in general short term parking for one or two hours

For short trips, e.g. for shopping, prices are between GBP 0.80 and 1.00 per hour. On street parking for 4 to 24 hour stays between GBP 3.70 and 4.20. In multi- storey car parks prices increase up to GBP 1.25 / hour for 6-hour stays and amount up to GBP 11 for stays between 9 and 24 hours.

Two areas have been defined with high and medium parking restrictions, the city centre inside the inner ring road and a surrounding belt of transport model zones, which are introduced into the mode choice model.

The City of Nottingham provides four Park and Ride sites outside of the city centre. Tickets for parking and public transport to the city centre cost between GBP 1.50 and 1.90. The modelling of this P+R demand requires some special activities which are described in detail below in section 4.3.

4.2.3 Impedances in the Transport Model

A conventional transport model comprises four stages. In three out of these four stages the impedance to travel between an origin and a destination is a key element:

Trip distribution: the impedance between two zones of a model determines the number of trips between these zones in relation to trips to other zones with the same attractiveness parameters.

Mode choice: different impedances determine mode choice

Traffic assignment: the preference of a particular route against another is determined by the impedances of links making up each route.

Only the first stage (trip generation) is independent of an impedance variable in the current "state of the art" of transportation modelling.

4.2.3.1 Trip distribution Impedances

The number of trips F_{ij} between two zones i and j is defined through the following "gravity model" equation

$$F_{ij} = O_i \frac{D_j \cdot f\left(w_{ij}\right)}{\sum_{k=1}^{K} \left(D_k \cdot f\left(w_{ik}\right)\right)}$$

where

F_{ij} No. of trips from zone *i* to zone *j*

O_i originating trips from zone *i*

D_j attractiveness of zone *j*

K No. of zones

$f(w_{ij})$ deterrence function: $f(w_{ij}) = e^{a w_{ij}}.w_{ij}^{\beta}$

α,β deterrence parameters

w_{ij} separation from zone *i* to zone *j*

The impedance or deterrence function includes two parameters:

(1) The separation term w_{ij} which is a generalised cost term – here the distance between the zones

(2) The deterrence parameters α and β are a set of parameters with different values for the perception of generalised costs in three dimensions: demand segment, activity, supply quality class. There is no explicit variable for direct costs (e.g. fares), however the perception of generalised costs by different person groups for their different activities is well reflected in the validated model. It is assumed, that cost parameters are primarily dependant on distance. The supply quality class describes the service level of Public Transport on a zone-to-zone basis and is determined primarily by the service frequency and the numbers of necessary transfers during the trip.

Figures 4.8 and 4.9 illustrate the different sensitivities to distance for the activities *work* and *shopping of daily goods*. It can be clearly seen, that commuters are more willing to travel longer distances than people going to shop. The comparison between model and survey are good.

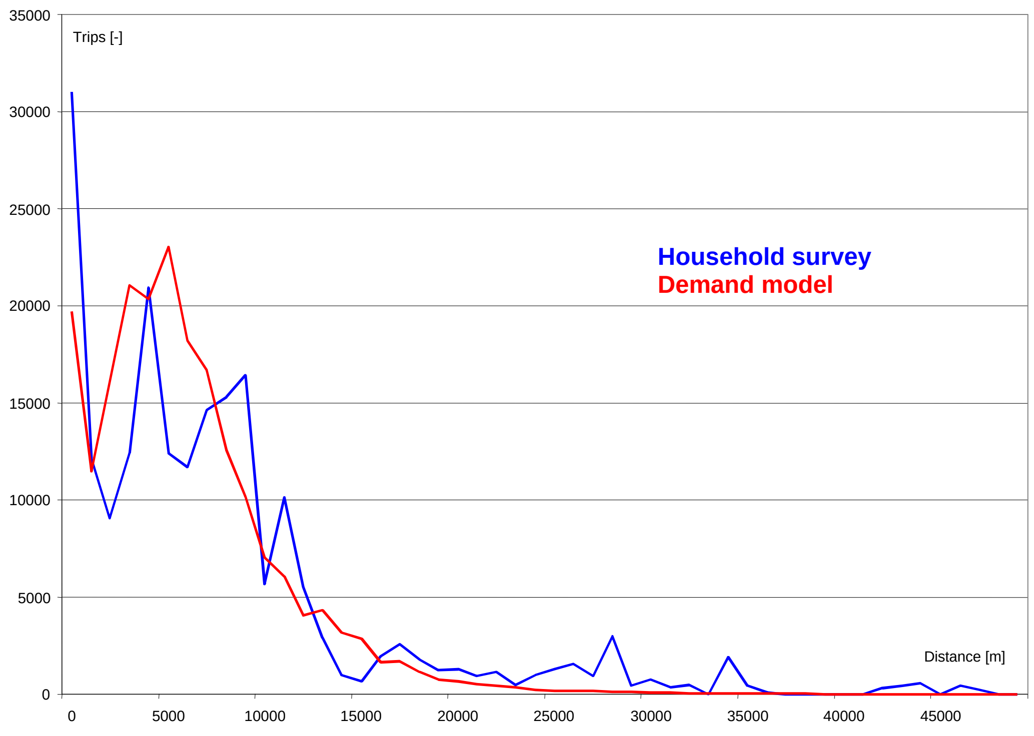

Figure 4.8 : Home to Work Trip Length Distribution

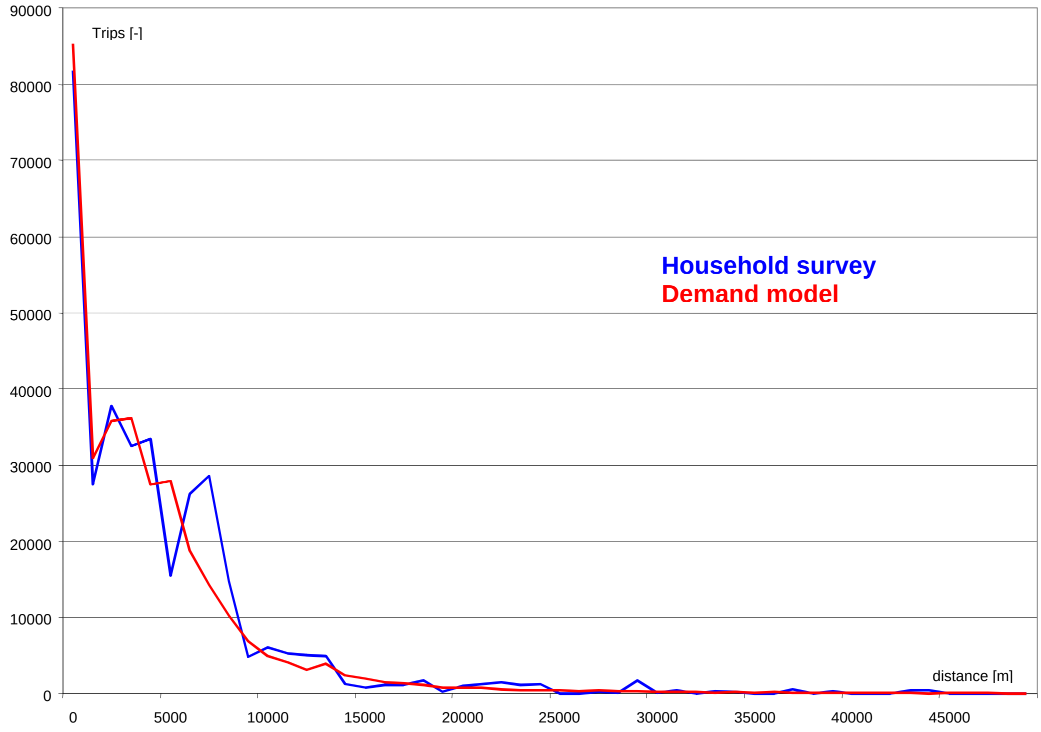

Figure 4.9 : Home to Shopping Trip Length Distribution

4.2.3.2 Mode Choice Impedances

Mode choice is modelled through a multi-nomial logit function of the form:

$$P_{gij}(m) = \frac{e^{U_{gij}(m)}}{\sum_{k=1}^{M} e^{U_{gij}(k)}}$$

with:

i, j indices of zones
m index of mode (M= total number of modes)
$P_{gij}(m)$ group-specific probability to choose transport mode *m* for the trip from *i* to *j*
$U_{gij}(m)$ group-specific utility function for transport mode *m* from *i* to *j*

The utility function is formally defined with seven parameters p_{igm} as

$U_{gij}(m) =$

$- p_{1gm} \times \mathbf{T}_{ij}(m)$	p_{1gm}	marginal utility of 1 minute travel time T
	$\mathbf{T}_{ij}(m)$	mode dependent journey time matrix
$- p_{2gm} \times \mathbf{Z}_{ij}(m)$	p_{2gm}	marginal utility of 1 minute access or egress time Z
	$\mathbf{Z}_{ij}(m)$	mode dependent access and egress times
$+ p_{3gm} \times \log_e(\mathbf{D}_{ij} / p_{4gm})$	p_{3gm}	marginal utility of distance D ("advantage-distance“)
	$\mathbf{D}_{ij}$	distance between the zones
	p_{4gm}	advantage-distance of mode m
$- p_{5gm} \times \mathbf{C}_{ij}(m)$	p_{5gm}	marginal utility of 1 monetary unit of travel cost C
	$\mathbf{C}_{ij}(m)$	mode dependent cost matrix
$+ p_{6gm}$	p_{6gm}	constant utility of transport mode m
$+ p_{7gm} \times \mathbf{A}_{ij}(m)$	p_{7gm}	marginal utility of 1 unit of any additional attribute A
	$\mathbf{A}_{ij}(m)$	mode dependent attribute matrix

These parameters are included in the A453 MMS model with the following data:

Journey times for private transport and public transport (p_1)

Access and egress times (p_2)

Distances (p_3 and p_4)

Combination of rail distance share and transfer times (p_5)

Initial waiting times and service frequencies for public transport (p_7)

Currently there is no explicit cost matrix included in the model. Parking costs have initially been reflected in the values for access and egress times of private transport in the city centre zones. Fares are included in an implicit way within the distance matrix.

If different fare schemes are to be modelled in future year strategies they may be reflected in the cost matrices in the model. The specification of parking costs can be included in the access/egress times by applying additional values of time deduced from the SP survey.

Since the applied method of assignment for public transport in the model is line based, it only uses estimated delays for changing (calculated as half the average headway). However, every change is charged with a ten minute time penalty. This is included in the assignment function, as well as in the indicator matrix of supply quality in the mode choice procedure. Waiting time at the beginning of a trip is treated slightly differently where half of the headway is applied for headways up to ten minutes and a sub-linear increase for higher values. Rail services are treated slightly differently from bus services with an advantage parameter. An additional cost matrix associated with parameter p5 in the utility formula contains combined weights for rail distance shares and transfer times.

4.2.3.3 Traffic Assignment Impedances

The assignment of private and public transport trips is based on journey times.

In Public Transport the journey times are determined by the time tables of the operators. Although vehicle seating capacities are modelled, these are not included as part of the service quality. In subsequent runs the capacity of the services may be changed by the modeller, however as yet there is no algorithm for this.

In private transport the journey time is modelled through the so-called BPR function which derives the link journey time from the initial journey time(without traffic), the current flow and the saturation flow:

$$current\ \ journey\ time = initial\ \ journey\ time * \left(1 + a * \left(\frac{flow}{c * saturation\ \ flow}\right)^{b}\right)$$

While the coefficients a and c are identical for all links (a = c = 1.0), links with one carriageway are provided with parameter b = 2.0 whereas links with two carriageways are allocated b = 5.0. The result is, that two-carriageway-roads attract comparatively more traffic in the unsaturated situation, but are blocked more effectively in the case of congestion. The setting of b is controlled through the link types in the network model.

Journey time has to be included, whilst other link based parameters may be added(such as road user charges, distances, and other costs which can be attributed to links).

Currently the modelling is based on journey times only. However, if road pricing schemes should be considered in the option cases, there are two alternatives methods to do this. A simple solution would be to include link based charges in the cost function and to use the same assignment method (the equilibrium method). The alternative would be to use a different assignment method for evaluating road pricing schemes, the French TRIBUT algorithm. We recommend that the first approach is adopted, since road user charging will probably only be one option in a set of scenarios whilst all the other options may not include this.

4.3 MODELLING PARK AND RIDE

4.3.1 Introduction

In the PTV vision software P+R is not included as a dedicated demand segment. It can be modelled however with some assumptions.

In a first step the impedances for the public transport legs of P+R trips have to be defined with the Assignment model. This requires a selection of potential destination zones by the modeller. Parameters for this determination would be the destinations and journey times of the available public transport services for the existing or potential P+R sites.

The destination zones have to be connected to the P+R sites. In the network model each P+R site has to be defined as a zone and a link. In the second step an assignment is made. This defines the number of clients for the P+R sites. The P+R links have a limited capacity, defined by the number of parking places and number of changes during a day. This allows inclusion of different trip purposes with different durations of stay (commuters, shoppers). Also costs for parking and bus fares can be defined in the impedance of these particular links.

In this first assignment the number of clients entering the P+R sites are estimated for the whole modelling area in competition to private transport on the whole journey. A second assignment is necessary to assign these travellers to the public transport leg and to provide their correct return trip. As it is not mandatory that for both directions of a journey the same connection of a zone is used, it has to be guaranteed, that P+R customers start their private transport return trip from the same place where they left their car. Therefore the P+R return trips have to be removed from the original matrix for the private transport segment and entered as new relations between the P+R site and their final destination. In this same model run the P+R clients have to be assigned to the public transport services between the sites and the city centre.

This stands for the 24-hour-model. According to the P+R survey from 1998 the following assumptions are made for the three other time periods:

- In the morning peak hour the average maximum arrival rate has been observed at 34% of the all-day-values. This results in 1.2*34% = 40% for arrivals and no returns in the modelled morning peak period.

- For the inter-peak periods between 11am and 2pm arrival rates of 21% and return rates of 17% have been observed as averages. The mode lling rate then lies at 7% in each direction.

- In the pm peak there are no arrivals and a rate of 33% of the daily returns leading to 1.2*33% = 40% of the daily return trips in the modelled pm peak period.

Modelling P+R required the split of the former demand segment *Passenger car* into three new demand segments *Passenger car / commuter*, *Passenger car / home*, and *Passenger car / other*, as they have different characteristics with respect to their potential for using P+R.

4.3.2 Nottingham Base Year

External data relating to the use of the four existing P+R sites was obtained from a survey made in 1998. Information about the P+R users origin, destination, trip purpose, and duration of stay was available.

P+R Matrices have been generated for the four modelling periods of 24 hour traffic, the AM peak, the PM peak and the interpeak.

4.3.3 Nottingham Future Years

The general approach for the generation of future year P+R matrices is the same as for the base year. However, the modelling of new sites or alternative price structures in future year modelling requires parameters that have been derived using the results of the SP survey. In the SP survey people were asked about their attitudes towards P+R including different costs and different services (connection to the city centre via bus or LRT).