FABER MAUNSELL

DFT RAIL MODELLING FRAMEWORK

MODEL DEVELOPMENT REPORT

JULY 2004

Job No:

Reference:

Date created:

Telephone: +44 (0) 20 8784 5784
Fax: +44 (0) 20 8784 5700
Website: http://www.fabermaunsell.com

Marlborough House
Upper Marlborough Road
St Albans
Hertfordshire AL1 3UT

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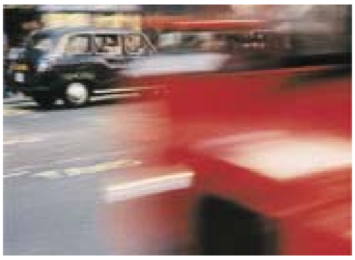
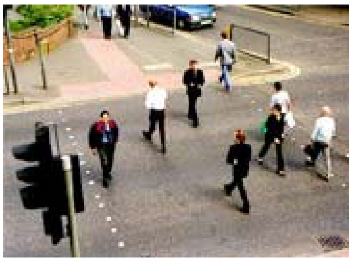
1 INTRODUCTION





1 INTRODUCTION

1.1 BACKGROUND

FaberMaunsell was commissioned by the Department of Transport, Local Government and the Regions (DTLR) in May 2001 to develop a national rail model framework as part of the Department's multi-modal modelling package to test the Government's TEN Year Plan strategies.

The National Transport Model (NTM) played a key role in the formulation of the Government's Ten Year Plan for transport. Since then, it has been undergoing a comprehensive programme of development to make it more integrated and spatially oriented.

One important element in this development has been the creation and inclusion within the NTM framework of the National Rail Model (NRM), to enable the impact of various transport policies to be assessed in a truly multi-modal fashion. As such, the emphasis has been on developing a model capable of capturing the strategic interactions between rail and other modes, rather then aiming to model in detail demand on particular rail routes. Nonetheless, the NRM comprises a geographical representation of the entire rail network, covering all stations on the rail system and the London Underground, and demands for its use. This integrates with the core mode-choice model of the NTM, known as "Pass1".

The main driver of rail demand, in response to a policy change, is the Pass1 multi-modal demand model. Being multi-modal it can test the impacts of non-rail policies on rail demand and the impacts of rail policies on non-rail demand. This is a key strength of the NTM and the primary role of the detailed rail model is to support this by generating robust rail costs and distributing Pass1 generated rail demands to the required spatial detail.

Thus the impacts on transport users of, say, rail infrastructure investment could be modelled, including not just the initial modal shift from roads, but also any ensuing feedback effects via changes in the costs of rail travel. Similarly, the model can also be used to estimate the impact of road policy schemes on rail use.

On the technical side, the modelling is complicated by the different spatial structures of Pass1 and the NRM. Pass1 works through area types - with, for example, all medium-sized urban towns in the same area type - and distance bands. The NRM, on the other hand, uses "real" geography.

The study also included the development of a set of Rail Policy User interfaces which have provided a friendly and efficient environment for the user to specify, for model testing, various rail service and/or policy changes associated with the Ten Year Plan.

1.2 STUDY OBJECTIVES

The brief provided a clear statement of the aim of the study as "*To develop a rail modelling system, compatible with the Departmental Pass1 model, that can be operated by DTLR to produce estimates of the effect, on core outputs and outcomes, of different rail policy choices.*"

Key attributes of the model framework were to provide a user-friendly interface to enable the model to be run efficiently without the need for specific modeling expertise. The model framework has also to be flexible to accommodate future changes in the Pass1 structure and to enable the user to specify changes to key parameters.

The philosophy in the model development process was to avoid hard coding of any variables so that the user can test the sensitivity of the model outputs to key demand drivers and to incorporate new data as it becomes available.

2 STRUCTURE OF NATIONAL RAIL MODEL FRAMEWORK



2 Structure Of National Rail Model Framework

2.1 THE NATIONAL TRANSPORT MODEL AND THE ROLE OF THE NATIONAL RAIL MODEL

The National Transport Model consists of a number of different modules that when combined form a multi-modal modelling framework. A simplified version of the general structure of the model, prior to the development of the National Rail Model Framework, is shown in Figure2.1.

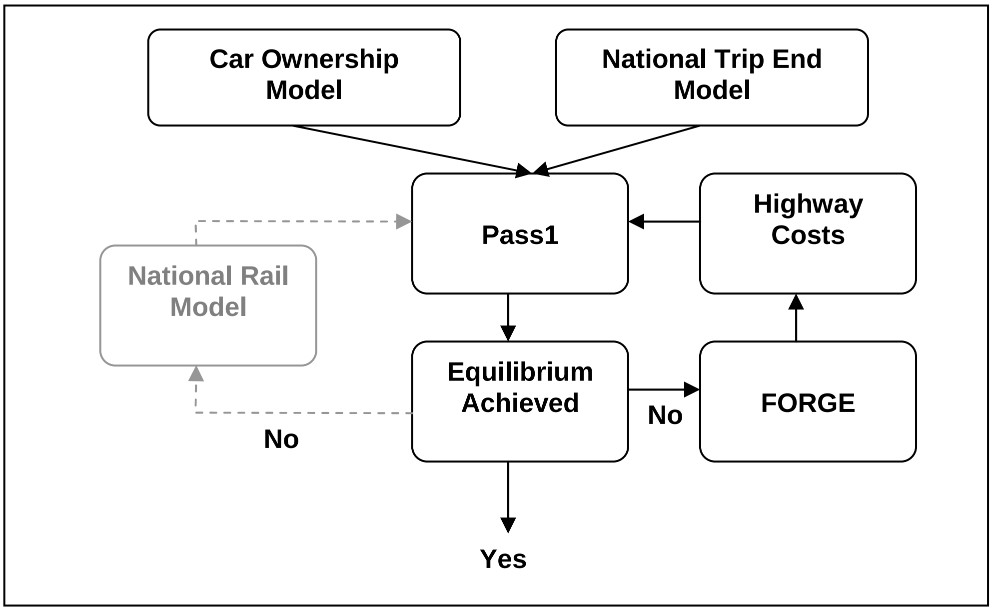


Figure 2.1 National Transport Model

The Pass1 model generates a multi-modal trip matrix based on modal costs and fixed trip generations/attractions. It has been linked to the FORGE model of highway congestion, via mileage profiles calculated from a highway assignment on a 10,000 zone network. The FORGE model outputs road generalised costs for input to the Pass1 process, and the whole system operates in an iterative manner until basic convergence is achieved after a small number of iterations.

In the above structure the public transport costs are derived in two separate ways. Firstly, the bus costs are based on NTS travel times and a set of relationships to calculate travel costs. Secondly the rail costs are based on relationships between travel distances, average rail speed and fare. The latter approach is very coarse and also unresponsive to changes in supply and demand.

To create a fully multi-modal model, it was necessary to create a detailed rail model, parallel to the FORGE model, so that the true interaction between public and private transport can be modelled at the required spatial detail within the model structure. The objective of the study was to develop the rail modelling framework and the necessary interfaces to the Pass1 model

2.2 OBJECTIVES AND CONSTRAINTS

The critical constraints placed on the model development process, and which influenced the process of model specification and development was that:

- The rail demand and network models should be calibrated against observed rail demands by conurbation and main corridor with a particular emphasis on the effect of crowding on route choice through the rail network in the south-eastern England;

- Passenger growth in the detailed rail demand model should be controlled to the predicted changes in rail demand output from the Pass1 model. The absolute figures from Pass1 are not used as controls for the total rail trips as the National Rail Passenger Matrices are considered to be more accurate in their representation of detailed rail demand. The Pass1 demand figures are at a relatively coarse spatial detail, but heavily disaggregated by journey purpose and person type / household type;
- Pass1 outputs are at the 24 hour level and therefore needed to be disaggregated to the time periods required to undertake the rail demand modelling;
- The model had to produce outputs that can be input to the TUBA cost-benefit analysis program; and
- The detailed rail network model should as far as possible be consistent with the PLANET model owned by SRA.

2.3 OVERVIEW OF NATIONAL RAIL MODEL FRAMEWORK

The National Rail model (NRM) framework has five key elements Detailed Rail Demand Model, Detailed Rail Network Model, Fares Model, DRNM to Pass1 Cost Aggregation and a Rail Policy User Interface. The relationship of these models and the interactions between them is depicted in Figure 2.2. The following sections outline the function of each module and the information flow through the model.

Detailed Rail Demand Model (DRDM)

This module produces the detailed rail demand matrices by time period and at a spatial detail compatible with the Detailed Rail Network model. Outputs at a 24 hour level, by journey purpose, are taken from Pass1, and disaggregated to time period and the Detailed Rail Network Model zone system, based on the patterns of demand in the National Rail Passenger Matrix (derived from CAPRI) by ticket type. This is a critical element of the process and required careful specification so that it provides a robust mechanism that takes account of factors such as improved attractiveness of stations or services, provision of park and ride facilities (Parkways), changes in demographic location, and changes in rail generalised costs, particularly where these are related to differential fare policies.

The inputs to this process are Pass1 matrices of rail demand by area type and the base year NRPM matrix by zone. The outputs of the module are then passed to the Detailed Rail Network Model in the form of zonal demands for assignment to the network.

Detailed Rail Network Model (DRNM)

The DRNM takes the detailed rail demand matrices from the DRDM and assigns them to the rail network to produce loaded passenger services and outputs on an individual route and line basis for use in detailed analyses. The model also provides rail generalised costs in terms of the different trip attributes, including in-vehicle time, wait time, access/egress time, fare, crowding, and interchange for input to the DRNM to Pass1 Cost Aggregation module. A critical decision in designing this model was that of zonal and network detail. The brief specified that the primary aim of the model framework in Phase 1 of the development of the National Rail Model was to establish a model that can differentiate between the main rail corridors and conurbations in terms of model outputs and is compatible with the National Transport Model Structure.

Rail Policy User Interface

Provides a user-friendly interface for the establishment of model runs. This is provided through a menu-driven interface to a database programme that enables the user to directly access the main elements of the network and model coding, so that changes can be made to individual services or groups of services in a consistent manner. This interface enables the user to make changes to service frequency, stopping patterns, rolling stock, run times and fares. The output from the Rail Policy User Interface are test network scenarios and revised fare matrices for use I the DRNM and DRNM to Pass1 Cost Aggregation module.

Fares Model

Provides a representation of rail fares on a point-to-point basis and allows for the potential of differential fares by time period and ticket type. The model is based on outputs from the DRNM that include point-to-point distance by individual routes so that alternative pricing policies can be modelled. The distance matrices are used to define relationships that replicate the fare structures in operation on different parts of the network. Inclusion of geographical indicators assists in refining the model to produce different fares within conurbations, i.e. London commuter fares are higher than Birmingham commuter fares. The output from the fares model is a matrix of fares for input to the DRNM to Pass1 Cost Aggregation module.

DRNM to Pass1 Cost Aggregation Model

Aggregates the generalised cost matrix output at zonal level from the detailed rail network model to the appropriate level of detail for use in the Pass1 model. In terms of the outputs, the effect of crowding is separately assessed so that it can be included with a different weight in the welfare cost calculations.

2.4 FRAMEWORK STRUCTURE

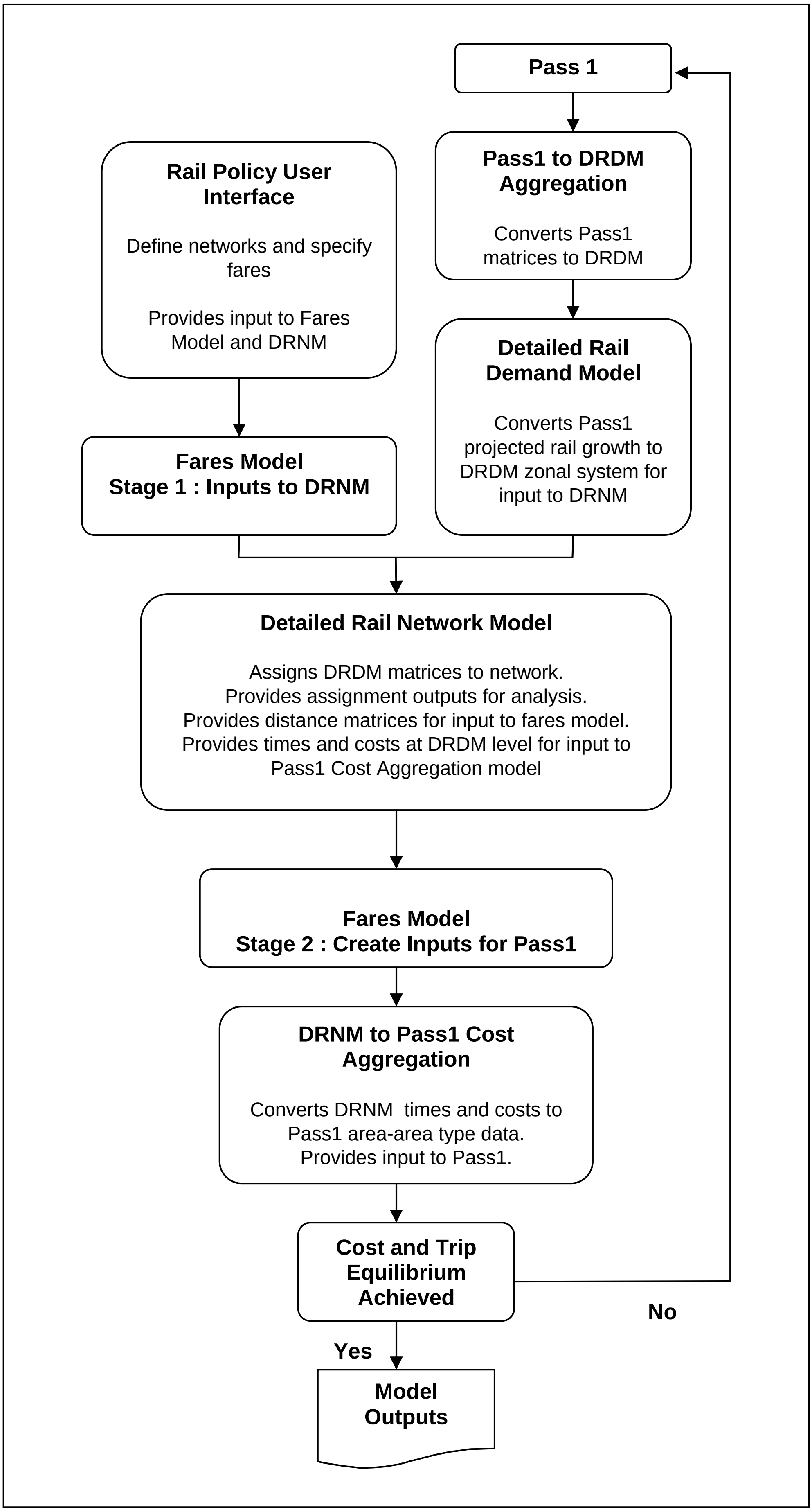
The overall model process is illustrated in Figure 2.2.

The main features of the model are that:

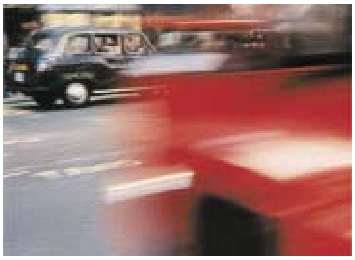
- The model has rail network and service representations for both AM peak and inter-peak periods, rail services being coded to the 1999/2000 timetable. It covers all British passenger rail operations in the UK;
- It uses the 1997 National Rail Passenger Model (NRPM) trip data as the base for the development of the Base Year (i.e., 1998) rail demand matrices, supplemented by the London Underground trips derived from FaberMaunsell's South East Regional Rail Model (SERRM), which in turn were developed from LATS data, as these are not included in the NRPM data;
- It adopts an incremental process such that the future year trips will use the base year rail demand travel patterns as the base, but the impacts of policies on trips in a future year are controlled by Pass1;
- For any model runs, future year trips from Pass1 will be automatically disaggregated to the DRDM zone level, using elasticity to population and generalised rail cost;
- It provides an option for updating demand matrices without going through the Pass1 interface by using elasticity to generalised time and cost, which also includes the rail fare elements;

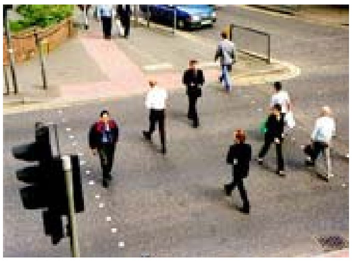
- An incremental public transport assignment process with a crowding time calculation mechanism to reflect the effect of overcrowding on routing and overall rail generalised cost;
- A set of Rail Policy User interfaces that provide a friendly environment for the user to specify for model testing various rail service and/or policy changes associated with the Ten Year Plan in ways which are efficient; and
- Model outputs that include passenger-kms, passenger-hours, PIXC indicators and emissions, all of which can be categorised by corridor and/or area type.

Figure 2.2 National Rail Model Framework



3 DETAILED RAIL NETWORK MODEL





3 Detailed Rail Network Model (DRNM)

3.1 CONCEPTS / OBJECTIVES

The Detailed Rail Network Model (DRNM) undertakes the assignment of the detailed rail demand matrices produced by the DRDM to produce loaded passenger services and outputs on an individual route and line basis for use in detailed analyses. The model also provides rail generalised costs disaggregated by the different trip attributes including in-vehicle time, wait time, access/egress time, fare, crowding, and interchange. These costs are then aggregated to an appropriate level of detail for input to the Pass1 model using the DRNM to Pass1 Cost Aggregation module.

3.2 ZONAL STRUCTURE

The critical considerations for the development of the zoning system were the structure of the Pass1 area types, the need to provide outputs by corridor and conurbation, and the need to have some form of compatibility with PLANET and LTS zones for future data transfer. A key factor in the decision process was the need to balance NRM spatial detail with the coarse Pass1 area types and distance bands. Pass1 has fifteen area types and thirteen distance bands.

The zoning system was developed with the following factors in mind:

- To represent Greater London at a detailed level such that the calibration of the model and hence assessments of peak period crowding effects can be satisfactorily undertaken;
- To represent other conurbations, like Greater Manchester, and West Midlands, etc, at a level that enables rail policies to be modelled;
- To allow for the main corridors, e.g. East Coast Mainline, Midland Mainline and West Coast Mainline to be identified separately;
- To allow for London and South East commuting and non commuting services to be identified separately; and
- To ensure the geographical representation of the model to be compatible with DfT's Pass1 model (NTEM Zoning system).

Therefore the principles adopted for the exercise are that:

- The zones should be direct aggregations of wards, and can be directly aggregated to Districts, and/or counties;
- The Greater London area and other conurbations should be more disaggregated for better modelling and assessment of peak-period crowding;
- Where an existing zone covers two competing rail corridors, it should be split so that these corridors can be identified separately; and
- The zones in the south East would be more disaggregated to take into account the complexity of the network.

The final decision was made on the basis of maintaining compatibility with the rest of the National Transport Model, and particularly the National Trip End Model, as information from these models are to provide key elements of the disaggregation process from Pass1 to the Detailed Rail Demand Model (DRDM). Fixing the zonal system to the NTEM zonal detail also provides a good representation of rail corridors and conurbations thereby enabling the required outputs to be achieved.

The Detailed Rail Network Model has a total of 1318 zones, the breakdown by Pass1 area type being summarised in Table 3.1.

Table A.1 in Appendix A provides a full list of the zones in the model, together with their corresponding NTEM zones, district and county names.

Table 3.1 Pass1 Area Type Description and Relation to DRNM Zonal System

Pass1 Area Type	Area Description	Number of Zones
1	Central London	9
2	Inner London	36
3	Outer London	58
4	North & East Metropolitan Areas	16
5	West Metropolitan Areas	19
6	North & East Conurbation surrounds	80
7	West Conurbation surrounds	58
8	North & East Urban Big Areas	17
9	West Urban Big Areas	7
10	South Urban Big Areas	22
12	North & East Urban Large Areas	6
13	West Urban Large Areas	5
14	South Urban Large Areas	31
16	Urban Medium	235
17	Urban Small & Rural	719

3.3 NETWORK PRINCIPLES

In order to provide flexibility for future enhancements of the model and also to facilitate a seamless interface through the Rail Policy User Interface a number of key decisions were made with respect to the physical structure of the model. The main decisions were to produce a physical network that represented all rail lines currently in use; all national rail and underground stations; and all new rail lines and stations that are under consideration for implementation in the next twenty years.

By coding the network at this level of detail it enables greater flexibility to change operational stopping patterns in the future and it also significantly increases the capability of the Rail Policy User Interface, which has a mapping link to the rail network, as it minimizes the need for the user to insert new stations and links. The insertion of new stations and links would require the user to access the EMME/2 databank and make the physical changes in EMME/2 thereby requiring knowledge of EMME/2. By providing a complete base year representation of the network, and as far as possible the future year changes, the model can be run through the Rail Policy User Interface without the requirement for EMME/2 expertise.

The following link types are used in the National Rail model:

- Centroid connectors to represent access times to the rail network
- Connecting walk links between underground lines and National Rail and underground stations
- LUL and other LRT links
- Docklands Light Rail links
- National Rail links.

Although LRT trips are not explicitly modelled in this version of the National Rail Model, several LRT links are included to provide better representation of connection time to National Rail services and to facilitate the modelling of LRT in the next phase of model development.

Link lengths are in kilometres. Grid co-ordinates are in tenths of kilometres from the OS datum. Centroid connectors adopt a weighted distance, which takes into account the proportions of trips using walk, bus or car as a feeder mode.

The physical rail network is shown in Appendix B.

3.4 TRAIN TYPES

To differentiate between the various types of rolling stock used on the network, a number of vehicle types have been used. Identifying different types of rolling stock used and their capacity is important, as this enables the model to reflect crowding effects and evaluate emissions at a sufficiently detailed level.

A full list of vehicle types used in the model is shown in Table A.2 in the Appendix A. The capacities listed in the table are an important input into the crowding assignment procedures.

Each service is coded into the model with a particular rolling stock type so that the individual service capacities can be modelled accurately.

3.5 SERVICE SPECIFICATIONS

The transit lines coded in the model consist of nearly all services operating in the UK in the summer 1999/2000 timetable. The model includes all National Rail services and a full representation of the London Underground and Docklands Light Railway. The periods modelled are:

Morning peak	representing 0700 – 0959
Inter peak	representing 1000 – 1600

The model represents the normal pattern of services in terms of trains per hour. This required some simplification, particularly in the peak period where services, although more frequent, tend to be less regular in relation to their arrival patterns.

Each line has been checked to ensure that its inter stop runtimes are as timetabled and that the correct routing and line capacity has been included in the model.

Future year service patterns have also been coded for the known schemes and aspirations. This includes the current version of the ten year plan.

A list of base year transit lines is shown in Tables A3 and A4 in the Appendix A.

3.6 ASSIGNMENT AND OVERCROWDING

3.6.1 Assignment Methodology

The assignment approach adopted in the model is based on the application of crowding factors to reflect the impact of capacity constraints on passenger perception of in-vehicle time in order to identify the routing effects within the assignment, and also in terms of generalized costs to be passed to Pass1 from a converged EMME/2 assignment. The crowded assignment technique is an iterative application of the standard EMME/2 assignment with differing runtimes dependent on the level of crowding in the model at each iteration.

EMME/2 is one of the most widely used public transport assignment models in the UK with the SRA's PLANET model, London Transports RAILPLAN model and now the DfT's National Rail model all based on EMME/2. Consequently the basic assignment algorithm has been well researched and applied.

The standard public transport assignment in EMME/2 is based on the concept of optimal strategies (Spiess and Florian, 1989)[1]. In short a strategy is a set of rules that allow a passenger to reach his destination. The number and type of strategies that a passenger may choose from depend on the information that is available during the trip. Strategies can therefore be simple or complex dependent on trip information availability. Examples of strategies include:

(1) Take line 1 to station X, transfer to line 3 and then exit at station Y;

(2) Take next train on line 1 or 2, if line 1 taken then exit at station y, if line 2 taken transfer at station Z and take line 3 or 4 to station Y; and

(3) Wait up to five minutes for train on line 1, otherwise take line 2, if at station Z you see express train on line 3 then transfer to line 3, otherwise continue to station W and then transfer to line 3 or 4 to complete the journey.

Within EMME/2 the assumption is made that the only information available to the passenger during his trip is that he finds out while waiting at a station/stop which line is to be served next. Consequently only strategies corresponding to the second of the above examples are considered.

The public transport route choice is hypothesized as "How does one find the path from A to B that minimizes the expected travel time?" By doing this one moves away from the concept that a passenger selects a single path from a set of possible routes. A passenger actually chooses a set of paths and then the first vehicle to arrive determines the path actually used. The choice process is therefore more complex.

Figure 3.1 shows an example network that is used to illustrate the concept of a strategy. The example shown contains 75 possible strategies to reach destination B from nodes A, X, and Y. However there are only five paths from A to B, four from X to B and two from Y to B.

The waiting time, in this example, is computed at each node by assuming that passengers wait on average half the arrival frequency, this can be user specified in the EMME/2 assignment. The line probability, the chance of a line being used, is the ratio of its frequency divided by the combined frequency.

In figure 3.2 the optimal strategy is described and the loadings for one hundred trips from A to B are shown. In this case the total unweighted travel times and loadings by path are shown in Table 3.2. This simple example illustrates how the EMME/2 algorithm achieves a multi-routing effect based on alternative strategies to reach a destination. It also highlights the importance of the frequency of services and the wait times estimated for each service on the routing through the public transport system.

Figure 3.1 Example Rail Network

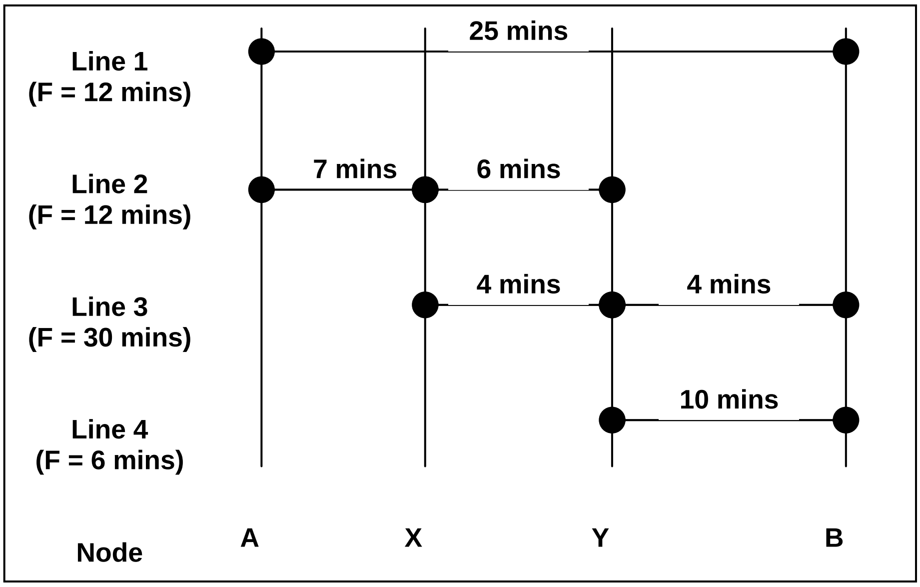


Figure 3.2 Optimal Strategy (A – B)

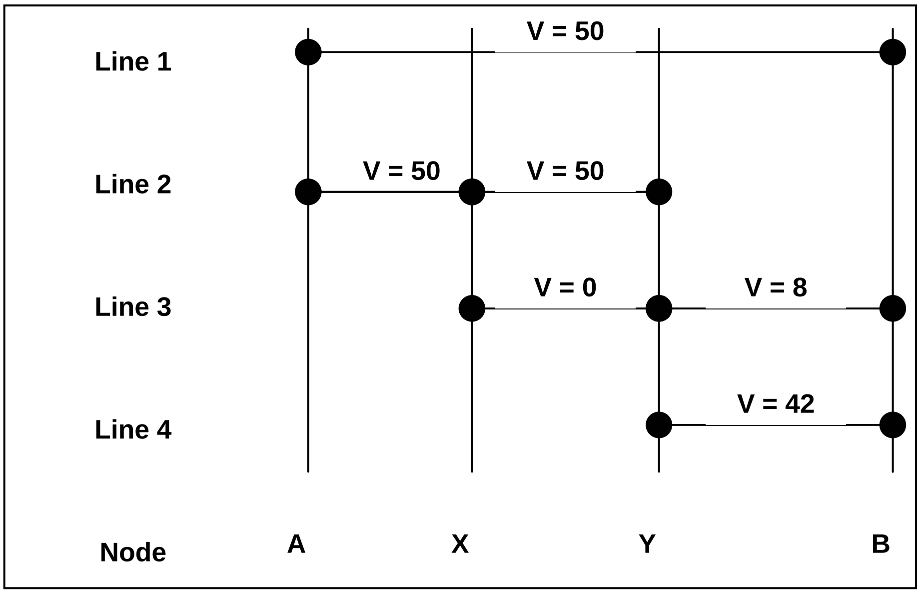


Table 3.2 EMME/2 Assignment Paths / Times

Path (A to B)	In Vehicle Travel Time	Waiting Time	Total Travel Time	Volume (%)
Line 1 A to B	25	6	31	50%
Line 2 A to Y Line 3 Y to B	17	21	38	8%
Line 2 A to X Line 3 X to B	15	21	36	0%
Line 2 A to Y Line 4 Y to B	23	9	32	42%
Line 2 A to X Line 3 X to Y Line 4 Y to B	21	24	45	0%

It can be seen from the above table that the algorithm identifies a set of attractive alternatives and then distributes the demand amongst the attractive routes.

3.6.2 Assignment Parameters

EMME/2 requires a number of parameters to be specified prior to the assignment each of which has an important effect on how vehicles are routed through the network. The main parameters are:

- Representation of service headway;
- Boarding times;
- Wait time factor which reflects the proportion of the headway that travellers will on average wait;
- Wait time weighting to reflect passenger perceptions of waiting time;
- Access/egress time weighting to reflect passenger perceptions of walking time to the rail system; and
- Boarding time weighting to reflect the propensity to interchange at individual locations.

Table 3.3 shows the assignment parameters applied in the assignments.

An effective headway adjustment factor is calculated to reflect the fact that waiting time for infrequent services is normally perceived as less than half the headway. With inter-urban services passengers will time their arrival at the station to catch specific timetabled trains and this is reflected in the model in order to prevent excessive wait times being generated.

The wait time factor used in the model is 0.5 and is applied globally for all services but to an effective headway rather than the actual headway. The effective headway is calculated as follows:

E_h = Headway if Headway < 15 minutes

E_h = 0.5*Headway*(1.81042 + Headway*(-0.00563)) for 15min< Headway < 60min

E_h = 0.5*Headway*(1.40671 + Headway*(-0.00262)) if Headway > 60min

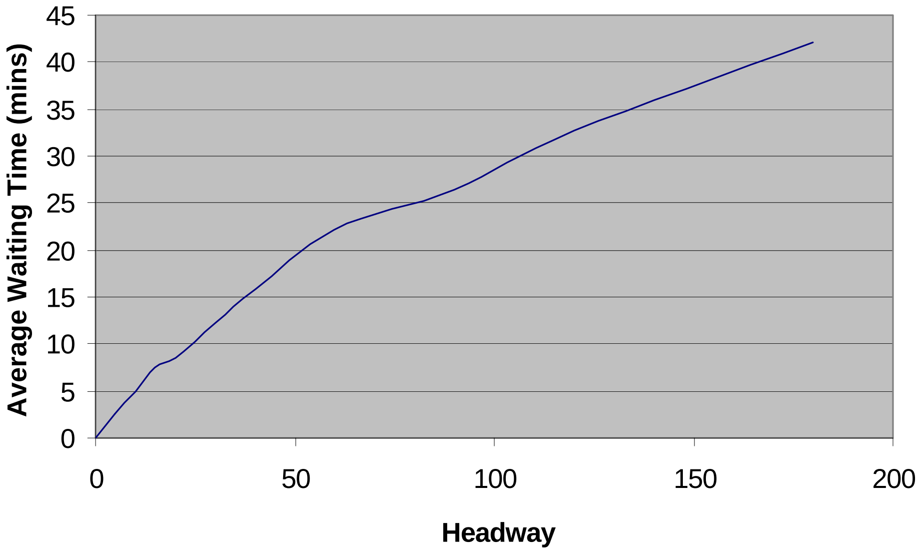
Where:

E_h = Effective headway

The equations for the calculation of effective headway have been derived from an assessment of PDFH guidelines for the equivalent time penalty for given service intervals (headway). The principle adopted is that the effective headway should be consistent with accepted practice for inter-urban rail modelling as encapsulated in PDFH. The equivalent time penalty can be considered as equal to the waiting time penalty for individual services which in turn is twice the average waiting time. Consequently the effective headway for a given service has been taken as the equivalent time penalty in PDFH and a continous relationship established as above.

The effective headway when combined with the wait time factor of 0.5 results in the average waiting times by passengers for different frequency services as shown in Figure 3.3.

Figure 3.3 Average Waiting Time (mins)



Boarding times are used to reflect the potential for interchange, and ease of interchange at certain stations where station facilities in terms of services such as waiting rooms and catering make interchange more comfortable. Also taken into account in setting the individual boarding times is the degree to which timetables have been constructed to make connection times better at certain locations. Each node, or station, in the network has a boarding penalty allocated to it with a general boarding penalty of 5 minutes for LUL/DLR stations and 10 minutes for British Rail stations. These are set to deter station interchange. Specific boarding times for certain stations were calibrated individually.

The wait time weight takes a value that is compatible with those generally used in public transport assignment models of 2.22. The peak and inter-peak assignment parameters are the same.

Table 3.3 Parameters Used For Assignment

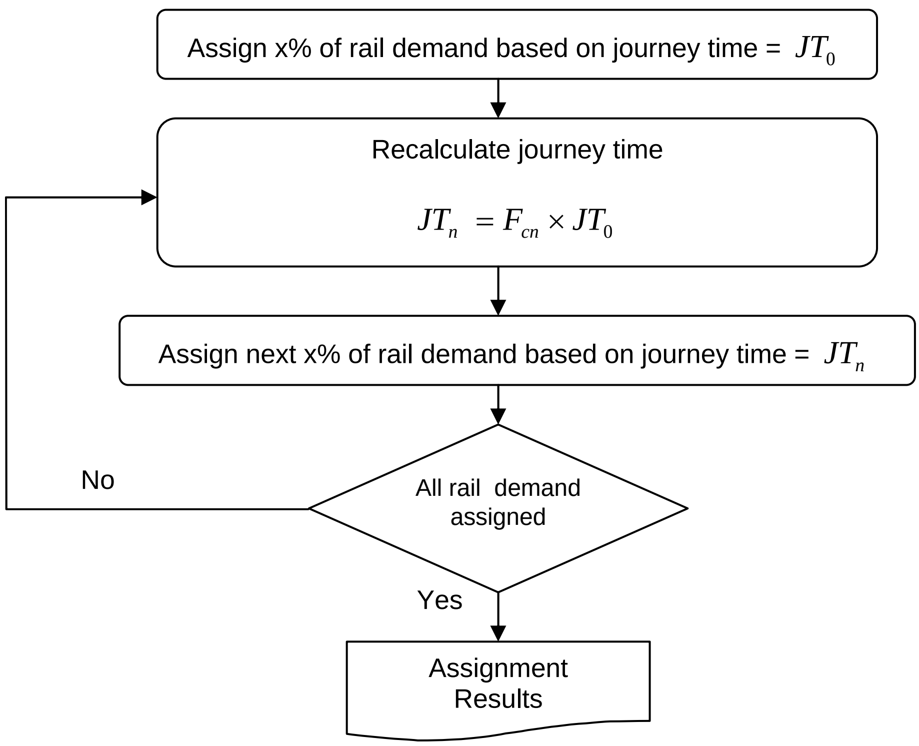
Parameter	Value of Parameter	General Source of Data	Specific Source
Source of effective headways	3	User defined line attribute	Ut3
Source of boarding times	2	Node specific	Ui1
Source of wait time factor	2	Node specific	Ui2
Wait time weight	2.22	Macro	-
Auxiliary transit time weight	2.81	Macro	-
Boarding time weight	1	Macro	-

3.6.3 Crowding

A key issue addressed by the Detailed Rail Network Model is that of the crowding effect. This is particularly relevant for services in main corridors and in main conurbations, as frequently rail demands for travel are greater than service capacities in the peak period, and as a result re-routeing often takes place to avoid over crowding. The mechanism used is the same as that in the FaberMaunsell SERRM model, but with some improvements on its convergence method. The method adopted is also compatible with that used in the PLANET and RAILPLAN models.

The approach can be described through the following steps, as shown in Figure 3.3.

Figure 3.4 Crowded Assignment Process



Step 1: assigns a proportion of the total rail demand matrix to the network, according to an initial set of generalised costs;

Step 2: calculates a new set of generalised costs, taking into account the crowding effect in the form of a time factor, calculated based on passenger loads and service capacities;

Step 3: assigns next proportion of total demand matrix according to the weighted average of the previous and current sets of generalised costs; and

Step 4: checks whether all demands have been assigned. If not, it goes back to step 2; otherwise, the process stops.

In the Detailed Rail Network Model both peak and inter-peak assignments require a sequence of incremental assignments separated by the application of a crowding function. The rail trip matrices are assigned incrementally for the number of iterations set by the user.

During the iterative process three rail matrices are assigned in sequence, representing the following three trip purposes:

- commuting purposes;
- business related purposes; and
- other purposes.

These three trip increments are calculated at the beginning of the assignment process by dividing the total rail trips for that segment by the number of assignment iterations. The total number of assignments is therefore 3 times the number of iterations.

For the morning peak period assignment, profiles of passenger demand distribution and train service distribution over the three-hour period have been used to better represent the relation between demand and supply sides of the rail network which is crucial to reflect the crowding situation. The three hour AM peak period is therefore split into 18 time intervals, each represent a 10-minute period. The profiles of passenger demand and train service distributions are shown in Table 3.4, and Figure 3.4. The profiles have been derived from counts of trains and passengers arriving in Central London by time period.

The function used reflects the effect of overcrowding by defining a crowding factor to be applied to rail journey times based on the following:

Figure 3.5 Calculation of Crowding Factors

$$F_c = 1 \quad \text{for} \quad V \leq 0.6 * C_s$$

$$F_c = 1.01 + 0.12 * (V - 0.6 * C_s) / 0.4 * C_s \quad \text{for} \quad 0.6 * C_s \leq V \leq C_s$$

$$F_c = 1 + \frac{1}{V} * [0.13 * C_s + (V - C_s) * (1.25 + 0.35 * \frac{(V - C_s)}{(C_t - C_s)})] \quad \text{for} \quad V \geq C_s$$

Where

F_c = crowding factor to be applied to journey times

C_s = seating capacity

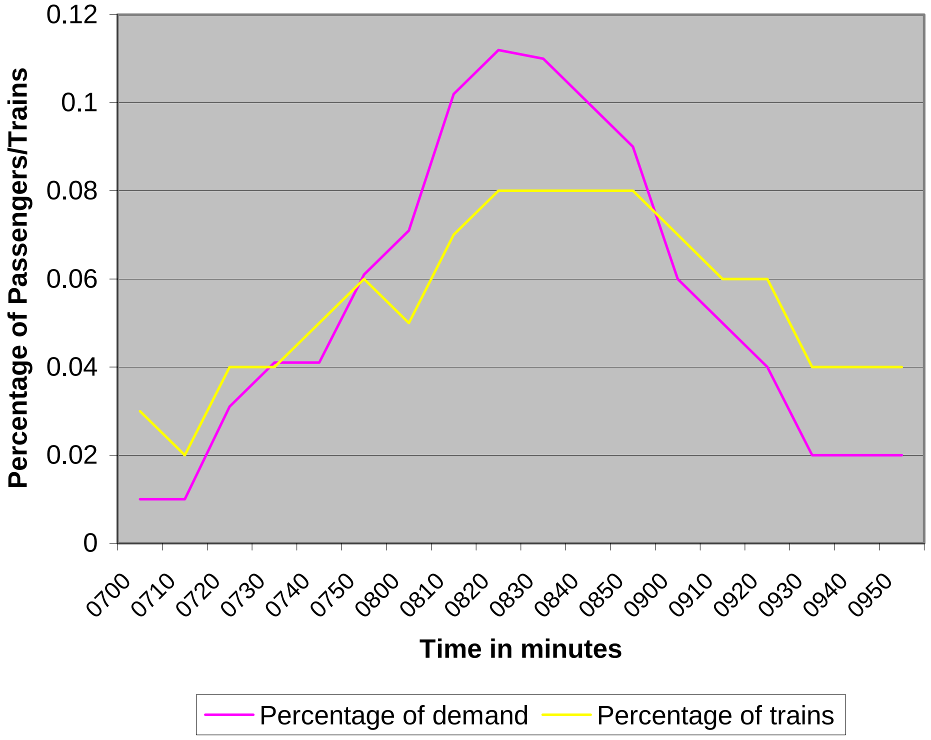
C_t = total capacity seating and standing

V = volume

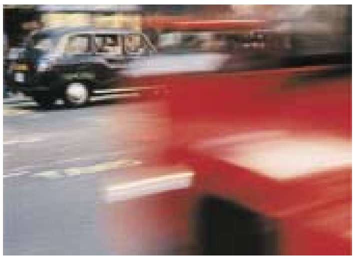
Table 3.4 Distributions Of Demand And Train Service (Am Peak Period)

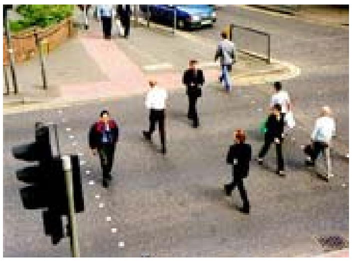
Time Interval Number (10-min)	Percentage of Passenger Demand	Percentage of Train Service
1	0.01	0.03
2	0.01	0.02
3	0.031	0.04
4	0.041	0.04
5	0.041	0.05
6	0.061	0.06
7	0.071	0.05
8	0.102	0.07
9	0.112	0.08
10	0.11	0.08
11	0.1	0.08
12	0.09	0.08
13	0.06	0.07
14	0.05	0.06
15	0.04	0.06
16	0.02	0.04
17	0.02	0.04
18	0.02	0.04

Figure 3.6 Passenger and Train Profiles : Crowding Assignment



4 DETAILED RAIL DEMAND MODEL





4 Detailed Rail Demand Model

4.1 STRUCTURE

The Detailed Rail Demand Model (DRDM) is the mechanism for producing spatially detailed rail demand matrices that reflect changes in rail demand predicted by Pass1 model runs. It brings together changes in rail demand from both income-related effects, and policy impacts. The basic process contained in the DRDM is summarized below:

- Develop base year rail demands at DRNM zonal level from the National Rail Passenger Matrix and other sources for London Underground trips;
- Develop time period matrices for assignment to the DRNM;
- Import rail growth forecasts from Pass1 model for future years or rail test scenarios;
- Apply the income growth elasticity model to take account of income related effects on rail demand; and
- Disaggregate the income adjusted Pass1 growth forecasts to the DRDM zonal system.

The processes described in this chapter and their linkages are shown in Figure 4.1. In the following sections we describe the key tasks undertaken and the individual models that have been established.

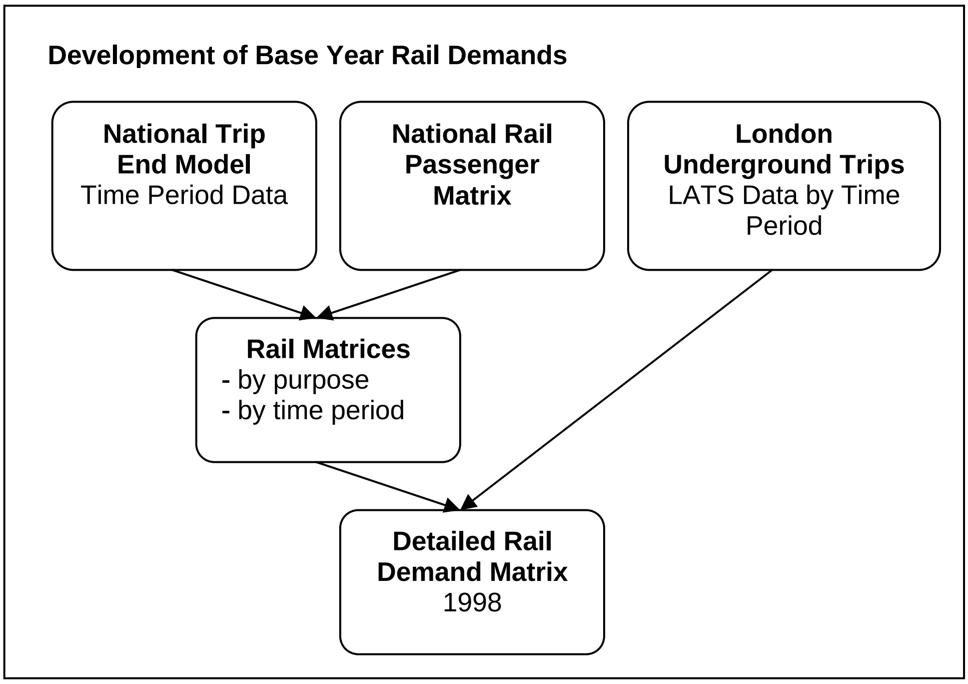
4.2 BASE YEAR RAIL DEMANDS: NRPM

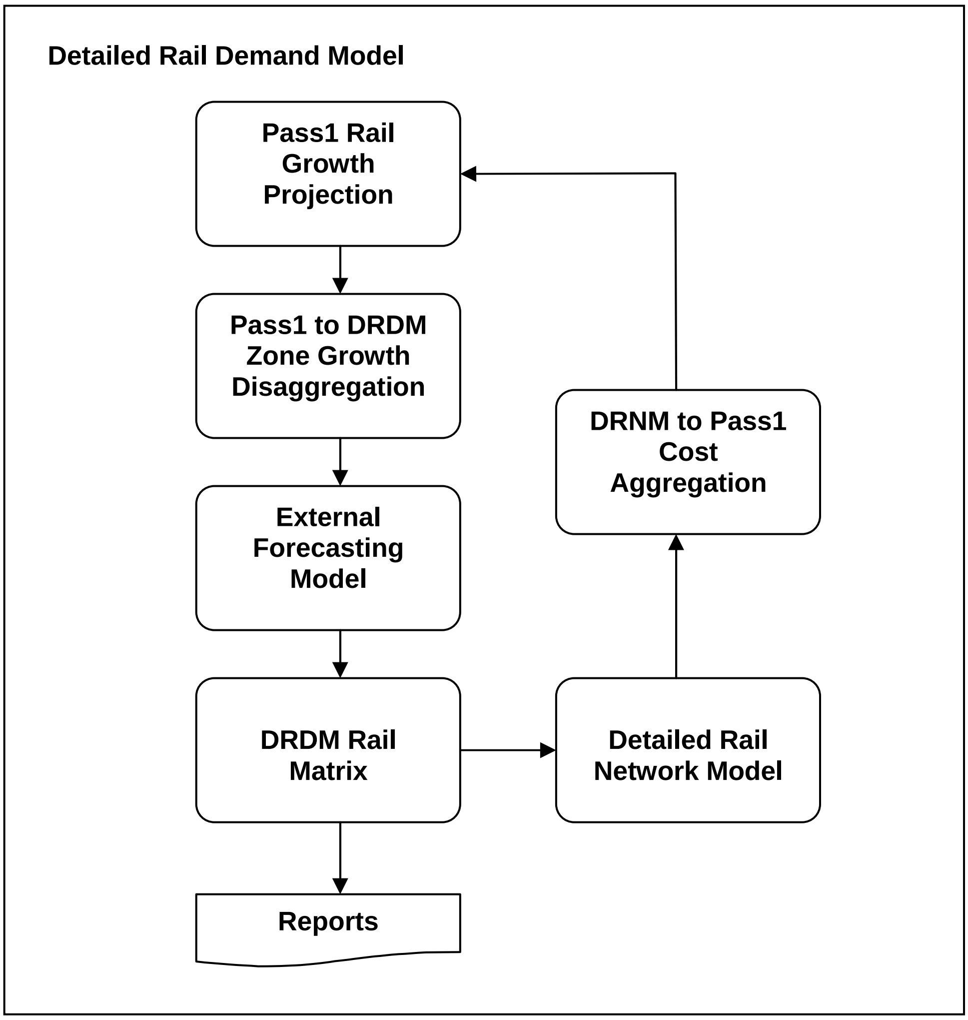
The 1997 National Rail Passenger Model (NRPM) rail trip data was used as the base for the development of our 1998 Base Year rail demand matrices.

The original NRPM trip data, provided by Peter Davison Consultancy (PDC), were segmented by 8 purposes and 2 car availability types. It is important to note that the total annual number of NRPM trips is about 586 million, 5 percent lower than that of CAPRI data, 617 million, which is the source of the NRPM matrices. This is due to a cut–off exercise undertaken by PDC when these matrices were produced for this Study, where if the total trips between two wards are less than 1, these trips are excluded. Therefore the NRPM matrices were factored up to the CAPRI trip total by a global factor of 1.05.

These matrices were then supplemented by London Underground trips derived from FaberMaunsell's SERRM model as they are not included in the NRPM matrices. The source of the London Underground trips was the LATS surveys.

Figure 4.1 Detailed Rail Demand Model





4.3 TIME PERIOD PROFILING

The methodology for developing base rail demand matrices by direction and time period was subject to a number of constraints. These constraints were created by data access and timescale issues. The study reviewed the potential options and concluded that there were four possible ways forward albeit with each option having some limitations or risks attached.

The four options can be summarised as follows:

(1) Incorporate demand profiling, through the use of ORCATS data, into the proposed 2000 National Rail Passenger Matrix up-date to be carried out by Peter Davidson Consultancy on behalf of DETR.

(2) ORCATS data on time periods to be obtained by PDC and applied to the 1997 NRPM along with production to attraction factors for conversion of the O/D NRPM to a P/A format.

(3) To obtain the 1997 NRPM apply the production and attraction factors and then apply the time profiles from the National Travel Survey.

(4) To obtain 1997 NRPM and apply production and attraction factors and time period splits based on the National Trip End time period splits and P/A factors.

A detailed assessment of the different options and the conclusions reached are summarised in the following sections.

4.3.1.1 Option 1: 2000 National Rail Passenger Matrix Up-Date

Option 1 was the best theoretical solution as it would have been based on 2000 production to attraction profiles from the CAPRI data that had the ORCATS time profiles applied directly to the data. This would have produced rail demand matrices by specified time periods, journey purpose and ticket type. The main drawback with this option was one of timescale in that the 2000 NRPM would not be available within the required timescale for the delivery of Phase 1 of the National Rail Model development.

4.3.1.2 Option 2: 1997 NRPM, ORCATS and P/A Factors

Option 2 eliminated the timescale issue associated with the 2000 NRPM up-date by using three sets of existing data:

- 1997 NRPM
- ORCATS time profiles
- Production to attraction factors, created from CAPRI tertiary level data to convert 1997 NRPM O/D matrix into P/A format for application of the ORCATS profiles.

This approach was dependent on the ORCATS profiles being made available and the disadvantage of this option is that there were still timescale issues involved in receipt of ORCATS profiles. Further concerns were that the ORCATS profiles are based on relatively old data, which predates privatisation, and as such there could have been recent changes that would preclude its use in such a detailed manner as that proposed in the DRDM.

4.3.1.3 Option 3: 1997 NRPM, P/A Factors and National Travel Survey Time Profiles

Option 3 was a low risk option in terms of timescale and impact on study completion yet would provide an acceptable technical solution for Phase 1 of the model development. The procedure would be as follows:

- Specify the detailed rail network zoning system
- Obtain the 1997 NRPM at the specified zone system
- Develop from tertiary level CAPRI data a set of production to attraction factors to be applied to the 1997 O/D NRPM to produce the directional profiles at P/A level by ticket type, purpose and car ownership
- Apply the time period profiles by purpose from the NTS to produce time period rail demand matrices by purpose, car ownership and ticket type
- Assign the time period matrices to the detailed rail network model and compare the modelled passenger loadings with the observed cordon and screenline counts by time period
- Adjust the time period matrices where necessary to reflect the observed counts if significant differences are identified

This approach would have provided a robust set of base year time period matrices whilst eliminating any timescale risks associated with obtaining external data permissions and interfaces with external consultants.

4.3.1.4 Option 4: 1997 NRPM, P/A Factors and National Travel Survey Time Profiles Based on National Trip End Time Splits

Option 4 was considered to be a further low risk option in terms of timescale and impact on study completion yet would provide an acceptable technical solution for Phase 1 of the model development. The procedure would be as follows:

- Specify the detailed rail network zoning system
- Obtain the 1997 NRPM at the specified zone system
- Develop from the National Trip End time split data factors to apply by purpose and car ownership to directly introduce directionality and time period matrices;
- Assign the time period matrices to the detailed rail network model and compare the modelled passenger loadings with the observed cordon and screenline counts by time period
- Adjust the time period matrices where necessary to reflect the observed counts if significant differences are identified

This approach would provide a robust set of base year time period matrices whilst eliminating any timescale risks associated with obtaining external data permissions and interfaces with external consultants. It would also be consistent with the time period work in the National Trip End model.

4.3.1.5 Summary

To summarise it was concluded that Option 1 the use of the 2000 NRPM update had too many associated timescale risks to be seriously considered but that incorporation of the 2000 data should be re-examined in the later stages. That Option 2, which relies on three separate data sources, including the ORCATS profiles to create the time period matrices also had timescale risks and involved the use of profiles based on old data.

Option 3 would have required permission to use CAPRI data for this study, however, Option 4 used information readily available to the study team and as such was adopted as the most appropriate mechanism for undertaking the time period profiling given the timescale and data constraints.

4.4 PASS1 MATRIX AGGREGATION

4.4.1 Background

There are two key stages to be undertaken in linking the Pass1 and DRDM passenger demands. These are:

- The aggregation of the Pass1 demands and NRPM matrices to a common basis in terms of trip purpose and market segmentation. This can be referred to as Pass1 matrix aggregation; and

- The mechanisms for allocating the Pass1 area-area type growth projections to the spatially detailed DRDM zonal level referred to as Pass1 to DRDM Trip disaggregation.

The first of these tasks was to establish appropriate mechanisms to aggregate Pass1 matrix outputs to a common base with the matrices available in the National Rail Passenger databank and to be used in the DRDM in terms of trip purpose and market segmentation.

The area-toarea trip matrices produced from the Pass1 model has 105 market segments for each of the 13 distance bands. The Detailed Rail Demand Model (DRDM) uses 16 National Rail Passenger Model (NRPM) matrices, segmented by 8 purposes and 2 car availability types.

4.4.2 NRPM Trips by Segment

The NRPM matrices have 16 market segments, i.e., 8 journey purposes and 2 car availability types. But they do not identify whether or not a trip is home-based. Table 4.1 shows the NRPM matrices by market segment.

Table 4.1 Market Segments of NRPM Matrices

Purpose	Car Available	No car Available
Work	1	2
School	3	4
Business	5	6
Shopping	7	8
Visiting Friends Relatives	9	10
Holidays	11	12
Personal	13	14
Sports/ents	15	16

4.4.3 Pass1 Trips by Market Segment

Pass1 trips, on the other hand, currently have 105 market segments, broken down by trip purpose, person type, SEG and car availability, but not all the permutations are available. Table 4.2 shows the Pass1 matrices by market segment.

Table 4.2 – Pass1 Matrices by Market Segment

Purpose	Person type	SEG	1 adult / 0 car	1 adult/ 1+ car	2+ ad / 0 car	2+ ad / 1 car	2+ad / 2+ car	All
HB Work	Full time emp	High Medium Low	1 6 11	2 7 12	3 8 13	4 9 14	5 10 15	
	Rest of pop'n		16	17	18	19	20	
HB EB	Full time emp	High Medium Low	21 26 31	22 27 32	23 28 33	24 29 34	55 30 35	
	Rest of pop'n		36	37	38	39	40	
HB Educ	Child (0-15) Full time emp Other 16-64 Pensioner		41 46 51 56	42 47 52 57	43 48 53 58	44 49 54 59	45 50 55 60	
HB PB / Shop	Child (0-15) Full time emp Other 16-64 Pensioner		61 66 71 76	62 67 72 77	63 68 73 78	64 69 74 79	65 70 75 80	
HB Rec / Visiting friends	Child (0-15) Full time emp Other 16-64 Pensioner		81 86 91 96	82 87 92 97	83 88 93 98	84 89 94 99	85 90 95 100	
HB Hols / Day trips	All persons							1301
NHB EB	All persons	High Medium Low						1321 1341 1361
NHBO	All persons							1381

4.4.4 Pass1 Matrix Aggregation

In light of the differences in definition between Pass1 and NRPM matrices common market segments have been defined that enable Pass1 trips to be related to NRPM trips so that future year growth in rail trips can be controlled by the Pass1 model when disaggregating Pass1 trips to the DRDM level.

It was decided that it would be appropriate to aggregate the 105 Pass1 matrices into seven common segments as follows:

(1) 1. Work

(2) 2. School

(3) 3. Business

(4) 4. Shopping

(5) 5. VFR

(6) 6. Holidays

(7) 7. NHB Other

Table 4.3 shows how the Pass1 matrices have been aggregated to the seven common market segments.

Table 4.3 Aggregation of 105 Pass1 Matrices to 7 Common Segments for DRDM

Common Segment	Pass1 Purposes	Pass1 Segments	NRPM Purposes	NRPM Segments
1. Work	HB Work	1-20	Work	1-2
2. School	HB Educ	41-60	School	3-4
3. Business	HB EB	21-40, 1321,1341 and 1361	Business	5-6
4. Shopping	HB PB / Shop	61-80	Shopping	7-8
5. VFR	HB Rec / Visiting friends	81-100	VFR	9-10
6. Holidays	HB Hols / Day trips	1301	Holidays	11-12
7. NHB Other	NHBO	1381	Personal, Sports/ents	13-16

In the above table, home-based and non-home-based employer business trips are combined together to become one market segment. This is because NRPM only has one corresponding segment for business trips.

The seven common market segments are not split based on whether or not they have car available for their journey on two grounds:

- It is not essential for DRDM to differentiate car available trips from non-car available trips; and
- There is no direct relationship between Pass1 trip segments and NRPM matrix definitions. For example, the proportion of trips that have a car available for their journeys is not explicitly known.

For each distance band there are seven corresponding market segments. This translates to 91 matrices in total to be produced from the Pass1 model for the DRDM. It is important therefore to make sure each of these matrices are uniquely identified. Table 4.4 shows the matrix numbering system.

Table 4.4 Pass1 Matrix Numbers for DRDM

Segment	DB1	DB2	DB3	DB4	DB5	DB6	DB7	DB8	DB9	DB10	DB11	DB12	DB13
1. Work	1	8	15	22	29	36	43	50	57	64	71	78	85
2. School	2	9	16	23	30	37	44	51	58	65	72	79	86
3. Business	3	10	17	24	31	38	45	52	59	66	73	80	87
4. Shopping	4	11	18	25	32	39	46	53	60	67	74	81	88
5. VFR	5	12	19	26	33	40	47	54	61	68	75	82	89
6. Holidays	6	13	20	27	34	41	48	55	62	69	76	83	90
7. NHB Other	7	14	21	28	35	42	49	56	63	70	77	84	91

For completion, the definitions of the 13 distance bands (DB1 to DB13) are listed in Table 4.5 and the 15 area types in Table 4.6 respectively.

Table 4.5 Distance Band Numbers And Distance Ranges

Distance band	Range (miles)
1	<1 mile
2	1 – 2 miles
3	2 – 3 miles
4	3 – 5 miles
5	5 – 10 miles
6	10 – 15 miles
7	15 – 25 miles
8	25 – 35 miles
9	35 – 50 miles
10	50 – 100 miles
11	100 – 200 miles
12	200 – 300 miles
13	>300 miles

Table 4.6 15 Area Types

Area Number	Description
1	Central London
2	Inner London
3	Outer London
4	North & East Metropolitan Areas
5	West Metropolitan Areas
6	North & East Conurbation surrounds
7	West Conurbation surrounds
8	North & East Urban Big Areas
9	West Urban Big Areas
10	South Urban Big Areas
11	- n/a in version 2.0
12	North & East Urban Large Areas
13	West Urban Large Areas
14	South Urban Large Areas
15	- n/a in version 2.0
16	Urban Medium
17	Urban Small & Rural

Note: Areas 11 and 15 are not available.

Having established the above correspondence lists a program module has been developed that takes the Pass1 outputs in their most disaggregated format and compiles the rail matrices to the level appropriate for input to the Pass1 to DRDM disaggregation process.

4.5 PASS1 TO DRDM DEMAND DISAGGREGATION

4.5.1 Background

Pass1 to Detailed Rail Demand Model Interface

One of the most critical issues in the development of the NRM framework is the relationship between the geographical systems used in the DRDM and the Pass1 model. The Pass1 model has a unique structure in that its treatment of travel demands and the changes introduced by transport policy measures or infrastructure is not geographically unique but based on area types which include locations from different geographical areas. This means that movements such as Southport to Liverpool and Macclesfield to Manchester would fall within one area-to-area-type movement in Pass1, yet they are geographically separated. This would have implications for how the DRDM integrates with Pass1.

A simple example to illustrate the problems would be that testing of improvements in West Coast Main Line services to Manchester would produce demand changes for the area-to-area type containing the Southport-Liverpool and Macclesfield-Manchester movements. In translating the Pass1 demand changes to specific geographical movements we would expect minimal changes in demand for Southport-Liverpool trips as a result of West Coast improvements but significant improvements in trips from Macclesfield to Manchester. However because of the Pass1 area-to-area structure, if Pass1 projected demand growths were applied literally to the geographical movements comprising the area-to-area types, then similar changes in demand would be observed for both Southport-Liverpool and Macclesfield-Manchester trips.

The DRDM therefore required a methodology that can test and demonstrate on a detailed spatial level the impact of specific schemes through the Pass1 model. This required mechanisms for preparing rail times and costs using the DRNM and DRDM that are consistent with Pass1 area–to-area types, trip purposes and distance bands. And then for taking the predicted rail growth from Pass1 and ensuring that the growth in rail trips is disseminated to the correct spatial movements, i.e. those movements where changes in rail times and costs had taken place.

DRNM to Pass1 cost aggregation

The first step in this process was to create a mechanism for converting DRDM zone pairs to Pass1 area types and distance bands, and for producing weighted time and cost matrices for use in Pass1. The first attempts at this, on paper a relatively easy task, resulted in a number of problems. In order to ensure that zone pairs would not migrate between distance bands as passengers re-route, the crow-fly distance between zones in the DRNM was used to allocate the movements to distance bands. However, when producing rail times and costs by area-to-area type and distance bands a number of anomalies appeared when compared to the Pass1 data.

For certain movements in the detailed rail model, the rail time reflects a long detour as there are no direct rail services between two points, and hence when compared with the crow-fly distance gives a very slow rail service. This highlighted the need to ensure that zone-pair combinations were appropriately weighted.

A second issue was some short trips where two zones have access/egress links to the same station, giving routes with zero rail time but non-zero crow-fly distance, and thus (if the modeller is not careful) infinite rail speed. Such movements were removed from the process of generating weighted average costs.

Thirdly a few area-type/distance combinations that existed in Pass1 (which used highway distance rather crow-fly distance) did not exist in the rail model, or vice versa. Thus in order to bring the two models to a common base the rail model zones were allocated to Pass1 area to area types /distance band cells using the same principles as adopted in the original Pass1 definition.

4.5.2 Methodology

It was important that the proposed approach could be easily implemented in EMME/2 and not need too much databank resources in terms of the number of matrices and computer run time. The methodology developed satisfied the above requirements and involves the following steps:

Step 1 - aggregate Pass1 matrices by area, purpose and distance band into 13 matrices, each of which is for a certain distance band, and has a size of 15x15 representing trips from one of the 15 areas to another. The demand disaggregation is then carried out for each of these 13 matrices separately;

Step 2 - create correspondence list between Pass1 and the detailed rail demand model. The current version of DRNM has 1318 zones and they have been defined in such a way that one or several DRDM zones can be aggregated exactly to a NTEM zone. This is important as a direct correspondence list can then be created between Pass1 area types and DRDM zones;

Step 3 - at DRDM zone level, create a distance indicator matrix so that matrix calculations can be constrained to a certain distance band at a time;

Step 4 - at DRDM zone level create an area type indicator matrix so that all OD pairs with the same origin area type, and destination area type can be identified;

Step 5 - calculate for each OD pair a value representing its relative attractiveness, compared to other OD pairs having the same area type indicator. The calculation of the attractiveness values takes into account the changes in rail generalised cost and population as well as existing rail trips.

Step 6 - the matrix of attractiveness can then be furnessed to the changes in rail trips from Pass1 model.

Step 7 – apply the external demand forecasting module to incorporate the effect of income growth on rail demand

The above procedure acknowledges the difficulties that are inherent in translating forecast changes in demand from a coarse zonal system to a more detailed zonal system. The process reflects the fact that the changes in demand will not be uniform over every detailed zone that comprises the coarser zone and that differential growth will occur as the changes in rail accessibility and supply will be different by area. As discussed earlier this is further complicated in the Pass1 to DRDM disaggregation process as the area types in Pass1 are not geographically constrained and an area-to-area type movement may contain for example trips from Stockport to Manchester, and Southport to Liverpool. With this added complexity the inclusion of attractiveness factors based on population and rail cost changes is essential if the predicted rail growth is to be focussed in the areas of future rail improvement and not artificially spread around the country.

4.5.3 Mathematical Representation

Stage 1: The base year detailed level demand matrix is aggregated to the Pass1 level which consists of 2925 categories (i.e. 15 areas by 15 areas by 13 distance bands), according to a correspondence table which allocates each origin-destination pair in the detailed model to one of the Pass1 categories. Therefore the base year rail trips at the Pass1 level is calculated as:

$$T_{abd}^{0} = \sum_{i \in a;\, j \in b} T_{ij}^{0} \delta_{ij}^{d} \ ,$$

where:

A – the set of 15 Pass1 area types;
a – one of Pass1 origin area type, ie, $a \in A$;
b – one of Pass1 destination area type, ie, $b \in A$;
D – the set of 13 Pass1 distance bands;
d – one of the 13 Pass1 distance bands, ie, $d \in D$;
I – the set of DRRM zones;
i – one of DRDM origin zones, ie, $i \in I$;
j – one of DRDM destination zones, ie, $j \in I$; and
δ_{ij}^{d} – distance band indicator for each origin-destination pair in the detailed model.

($\delta_{ij}^{d} = 1,$ if the distance from i to j is in band d, $\delta_{ij}^{d} = 0,$ otherwise)

And the forecasting year rail trips at the Pass1 level is:

$$T_{abd}^{1} = T_{abd}^{0} + G_{abd}$$

Where:

G_{abd} – matrix contains changes in rail trips between the forecasting year and the base year, and is generated from the Pass1 model.

Stage 2: This step involves disaggregating the forecast year Pass1 rail trips calculated above to the detailed demand level, through the concept of the attractiveness matrix, which calculates a relative weight for each origin-destination zone pair in the detailed model, based on which the Pass1 trips for a given area by area by distance band combination can be allocated to their corresponding detailed model zone pairs accordingly. The attractiveness matrix is calculated based on changes in population and generalised costs (including travel elements of in-vehicle-time, assess/egress times, waiting times and travel costs), on their base year values. The equation for the attractiveness matrix is:

$$S_{ij}^{1} = T_{ij}^{0} R_i^{\alpha} \left(\frac{C_{ij}^{1}}{C_{ij}^{0}} \right)^{\beta}$$

Where:

S_{ij}^{1} – rail attractiveness indicator for trips from i to j;

T_{ij}^{0} – base year rail trips from i to j;

R_i – ratio of the forecasting year population value to the base year population value for zone i. The value is derived from the Department's Trip End Model (NTEM). When an NTEM zone contains several DRDM zones, then the same ratio applies to all these zones;

C_{ij}^{0} – base year rail generalised cost from i to j;

C_{ij}^{1} – forecasting year rail generalised cost from i to j; and

α – elasticity to population; and
β – elasticities to generalised cost, by trip purpose and area type.

Stage 3: The calculation of the forecast year detailed rail trips, T_{ij}^{1}, is:

$$T_{ij}^{1} = \frac{S_{ij}^{1}\delta_{ij}^{d}T_{abd}^{1}}{\sum_{p\in a;q\in b}\left(S_{pq}^{1}\times\delta_{pq}^{d}\right)}$$

Stage 4: Application of income elasticities to take account of unmodelled effects in the Pass1 model using the following:

$$T_{ijtk}^{2} = T_{ijtk}^{1}\left(\frac{GDP^{1}}{GDP^{0}}\right)^{\theta_{tk}}$$

Where:

T_{ijtk}^{2} – forecast rail trips from i to j taking into account income effects;

M – the set of three market segments, business, commuting and leisure;

t – one of the three market segments, ie, $t \in M$;

Z – the set of four geographical areas;

k – one of the four geographical areas, ie, $k \in Z$

θ_{tk} – the income elasticity of rail trips for segment t in area k

Stage 5 : Creation of rail times and costs for input to Pass1. This requires the creation of a weighted average time or cost for each rail trip attribute based on aggregations of detailed rail model zone to zone movements to the Pass1 area to area and distance bands. The procedure is undertaken as follows:

$$PC_{abd}^{r} = \frac{\sum_{i\in a, j\in b} T_{ij}^{2}C_{ij}^{r}\delta_{ij}^{d}}{\sum_{p\in a;q\in b} T_{pq}^{2}\delta_{pq}^{d}}$$

Where

C_{ij}^{r} = rail cost for attribute *r* for zone *i*, to zone *j*, for distance band *d*

PC_{abd}^{r} = rail cost for attribute *r* for input to Pass1 area *a*, to area *b*, for distance band *d*

r - is one rail attribute from the list of in vehicle time, wait time, access/egress time, interchange and fare

4.6 EXTERNAL DEMAND FORECASTING MODEL

The impacts of changes on rail demand over time - in particular, income growth - are handled within the NRM, rather than Pass1. Explicit income elasticities and time trends are applied to achieve this.

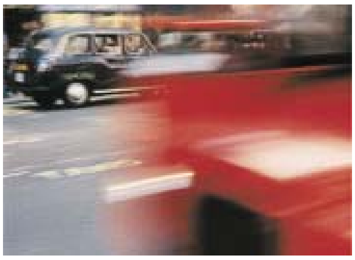
The rail demand income elasticity implied by the NTM is lower than that suggested by econometric time series evidence. In order to account for the additional rail overcrowding that would result from the higher level of income related growth in patronage, the levels of demand that are assigned in the rail model are boosted using income elasticities and time trends from time series modelling.

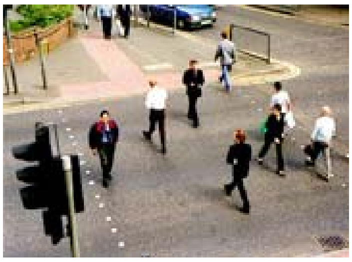
The effect is that Pass1 is used as a cross-sectional tool, rather than a time series one, to estimate responses to cost changes. In order to avoid double-counting, the increase in rail trips attributed to the time series element of Pass1 is stripped out.

The elasticities are disaggregated according to three market segments (business, commuter and leisure) and four different areas (SouthEast-London, London Intercity, SouthEast-Non London and Other), giving twelve different income elasticities in total. GDP forecasts are based on advice from HM Treasury.

The detailed rail demand model uses the outputs from Pass1 converted into the three different trip purposes (business, commuting and leisure) at the level of 1318 zones. The external forecasting module adjusts these demands to incorporate the effects of external factors which change over time, such as income growth. This results in the detailed rail matrices used in stage 4 in section 4.4. This procedure is run iteratively until the change in rail demand outputs has converged.

5 DEMAND AND NETWORK MODEL VALIDATION





FABER MAUNSELL

5 Demand and Network Model Validation

5.1 OVERVIEW

The National Rail Model operates in an incremental manner with the Pass1 model providing changes in rail demand at a very strategic level as a result of policy or infrastructure changes. These changes are then applied to the base year rail demands and the impact on the rail network derived. It is important therefore that an acceptable representation of the base year rail demands is contained in the model and that the network assignment process produces comparable modelled passenger flows by route and corridor when compared with actual passenger demand.

The model has therefore been validated in two stages. Firstly the passenger demands have been validated by comparing modelled rail demands by operator across key cordons where reliable rail passenger data exists. In the course of the model development the data available for the validation process was limited to a database of flows entering and leaving London, and global information on passenger mileage by operator.

More detailed count information is being compiled by SRA but at the time of the study this was not available. It is intended that the model be up-dated to include the 2000 National Rail Passenger Matrix in the near future and at that time the validation would be revisited with new count data from SRA.

It should be noted however that the National Rail Model has been developed to fit within an existing modelling framework that operates at a very coarse level of spatial detail, and as such a balance has to be struck between the level of validation expected given the nature of the overall National Transport Model and the objectives of the tests to which the model will be applied.

5.2 PASSENGER DEMAND VALIDATION

There are two elements to the passenger demand validation and these are:

- Comparison of total passenger kilometres; and
- Comparison of passenger flows across key cordons around London.

The actual passenger kilometres travelled on the rail network by Sector are shown in Table 5.1 for 1997-98, which equates to the base year for the NRPM demands. The actual total of 40.66 billion per year compares well with the modelled total of 41.58 billion.

Table 5.1 Base Year Passenger Kms by Sector

Sector	Observed	Modelled	Modelled/ Observed
London South East	22,584	23,625	+5%
Regional	6,259	5,777	-8%
Inter City	11,820	12,178	+3%
Total	**40,663**	**41,580**	**+2%**

Note. Figures are in millions of passenger kms per annum.

The figures show that the model provides a good representation of the total demand with only a 2% variance from the SRA quoted figures. The individual sectors are also reasonably represented with each modelled sector being within 10% of the observed. Table 5.2 shows the passenger volumes crossing the cordons around London.

Table 5.2 Passenger Flows by Time Period and Direction: Greater London

Cordon/ Direction	Peak Period			Inter Peak		
	Observed (‘000’s)	Modelled (‘000’s)	% Difference	Observed (‘000,s)	Modelled (‘000,s)	% Difference
Inbound						
Central London	395	384	-2.8	136	129	-5.1
Inner London	382	381	-0.3	127	129	+1.6
Outer London	180	186	+3.3	70	80	+14.3
Underground	360	335	-7.0	233	230	-1.3
Outbound						
Central London	35	48	+37.1	96	116	+20.8
Inner London	44	43	-2.3	93	117	+25.8
Outer London	25	26	+4.0	55	83	+50.9
Underground	104	105	+0.1	198	194	-2.0

The figures in Table 5.2 show that:

- The inbound and outbound passenger demands during the morning peak period are modelled to a high degree of accuracy with most cordon crossing flows being within 5% of the counts;
- In the morning peak period only the outbound flow on the central cordon is significantly different from the observed, however this is on a relatively minor flow in relation to the inbound flows; and
- The inter-peak validation for inbound passengers is generally good but that the outbound validation is poor, with the exception of the underground flows.

The poor comparison in the outbound inter-peak direction is a function of the way that the time period profiling has been derived in the modelled matrices. The inter-peak matrices are effectively directionally balanced as an average balanced inter-peak profile has been adopted. The counts will reflect some imbalance in the inter-peak flows which is not reflected in the model.

Overall the figures in Tables 5.1 and 5.2 show that the passenger demand matrix is a good representation of rail demand in the UK for the base year.

5.3 RAIL NETWORK ASSIGNMENT VALIDATION

The discussions in the previous section have established that the model contains a good representation of passenger demands in total. However of equal importance is the ability of the network model to correctly assign the demand to the correct services and to fully reflect the routing choices made by travellers.

To examine this aspect of the model, data has been compiled on the passenger kms by operator and the passenger volumes by section of line across the Greater London Cordons. Before proceeding to show the modelled and observed comparisons it is pertinent to note that the observed passenger volumes are derived from a one day count at the cordons around London and as such they are subject to daily variation, particularly in respect of the route taken on individual days. The demand matrix is based on annual ticket sales data and as such will provide an average usage of each route or corridor based on the assumption that the travel patterns are the same each day and that the system is operating perfectly. Clearly therefore one would expect differences between the counts and the modelled flows and this should be acknowledged when viewing the figures.

Table 5.3 shows the observed and modelled base year passenger kms by operator, the operators are not identified in the table for commercial reasons. Figure 5.1 also shows the modelled and observed flows.

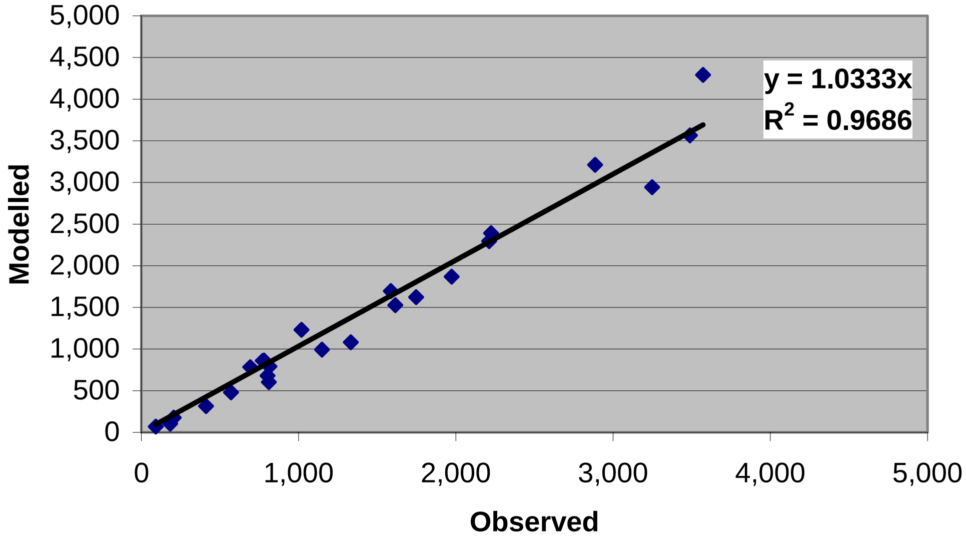
Table 5.3 Base Year Passenger –kms by Operator

Operator	Modelled/ Observed
1	-7%
2	+11%
3	+4%
4	+8%
5	-5%
6	-9%
7	-5%
8	+21%
9	+2%
10	+12%
11	-19%
12	+11%
13	-3%
14	-15%
15	-14%
16	+13%
17	-24%
18	-43%
19	+20%
20	+7%
21	-25%
22	-16%
23	-26%
24	-14%
25	+10%
Total	**+2%**

The figures in Table 5.3 generally show a good comparison of the observed and modelled passenger kms with the major operators being with +/-15% of the observed. The major percentage differences occur for the smaller operators. Overall the comparison indicates that the demand matrix and network assignment model combine well together over the network as a whole to produce an acceptable representation of rail demands.

Figure 5.1 shows that the modelled passenger kms are a good fit to the observed with a slope that varies from one by only 3.3% and an R^2 of 0.97.

Figure 5.1 Comparison of Observed and Modelled Passenger Kms by Operator



Tables C1 to C16, in Appendix C, show the comparisons of observed and modelled demands on the following cordons:

- Central London cordon, represented by the main station termini in Central London;
- Inner London cordon, which generally equates to the cordon represented by the North and South Circular roads; and
- Outer London Cordon, which is represented by the line of the M25.

The tables provide passenger flows by peak and inter-peak and for inbound, to London, and outbound trips.

A key indicator of the effectiveness of the assignment model in reproducing route choice across the various cordons is the R^2 coefficient obtained from a linear regression of the observed and modelled route passenger loadings and the slope of the fitted relationship. These are shown in figures C1 to C16, in Appendix C, and summarised in Table 5.4 below.

Table 5.4 Summary of R^2 and Regression slope Values for Cordon Comparisons

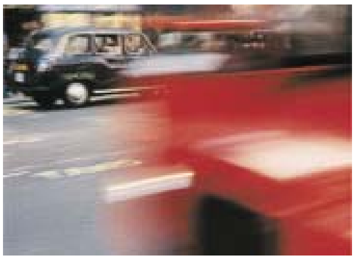
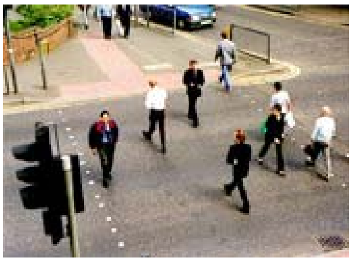
Direction/ Cordon	Peak		Inter-Peak	
	R^2	Slope	R^2	Slope
Inbound				
Central London	.99	0.98	.94	0.93
Inner London	.97	1.00	.90	0.97
Outer London	.96	0.99	.98	1.13
Underground	.91	0.94	.76	1.03
Outbound				
Central London	.34	1.16	.83	1.21
Inner London	.61	0.82	.81	1.27
Outer London	.75	0.86	.96	1.44
Underground	.45	0.85	.56	0.92

Table 5.4 shows the following key points:

- That the model replicates route choice in the AM peak period inbound very well with all **R^2** values in excess of 0.91, and regression slopes between 0.94 and 1.00;
- That the model is equally well validated in the inter-peak inbound direction for the primary rail cordons with **R^2** values in excess of 0.90, and regression slopes between 0.93 and 1.13;
- That the inter-peak outbound direction is slightly less robust with the underground flows dropping to an **R^2** of 0.56; and
- That the outbound direction in the AM peak is relatively poorly validated but that this relates to the minor flows in the model as a whole.

Overall it is concluded that the model has a strong validation in both demand and assignment terms and represents a robust basis from which to undertaken policy, infrastructure and service changes. The model is validated to an acceptable degree in relation to existing guidelines for the validation of public transport models with respect to the degree of correlation observed at the key cordon used around London.

6 FARES MODEL


6 Fares Model

6.1 BACKGROUND

The aim of the Rail Fares Model is to provide a reasonable representation of rail fares on a point to point basis and also to allow for the potential of differential fares by time period and operator, i.e. premium pricing. The model is based on outputs from the Detailed Rail Network Model that includes point-to-point distance. The distance matrices were then used with boarding matrices to define a series of fare relationships that replicate the fare structures in operation on different parts of the network.

The model is structured to provide outputs that are compatible with the Pass1 inputs on fares, that is currently a linear relationship. The required output is the composite average fare for each area and distance band in the Pass1 definitions. The detailed rail demand matrices and the DRDM/Pass1 correspondence list are used to compile a composite cost.

The Rail Policy User Interface enables the fares to be changed either globally or on an individual corridor basis. The effect of such changes are then reflected in the output composite costs. For example different pricing strategies by type of movement will have different impacts by corridor and as the Pass1 inputs can contain separate corridor effects within one category it is essential that the weighted effect of the fare changes are properly reflected.

This section outlines the process used to calculate the distance based fare matrices. The aim of this work was to calculate a matrix for National Rail and London Underground Rail fares for a number of user classes (Full Fare, Reduced Fare and Season Fares).

6.2 NATIONAL RAIL

The fare relationships for National Rail Network journeys were developed from a sample of actual fares for three different ticket types, namely full, reduced and season tickets. Actual fares, for each type of ticket, for 40 possible journeys were obtained and after preliminary examination they were grouped into three categories:

- Less than 50km
- Between 50 and 300km
- Greater than 300km

The fares obtained were all for return journeys with the season ticket fares converted to return fares by dividing the monthly fare by 21.67. This gives an equivalent fare based on the number of working days in the month.

The categories of fare types were then plotted to show the curve of the fare structure by ticket type and distance band and a formula to calculate fares based upon distance and ticket type was then calculated. This formula when applied to distance creates a corresponding fare. Table 6.1 shows the coefficients that were developed for each distance and fare type category.

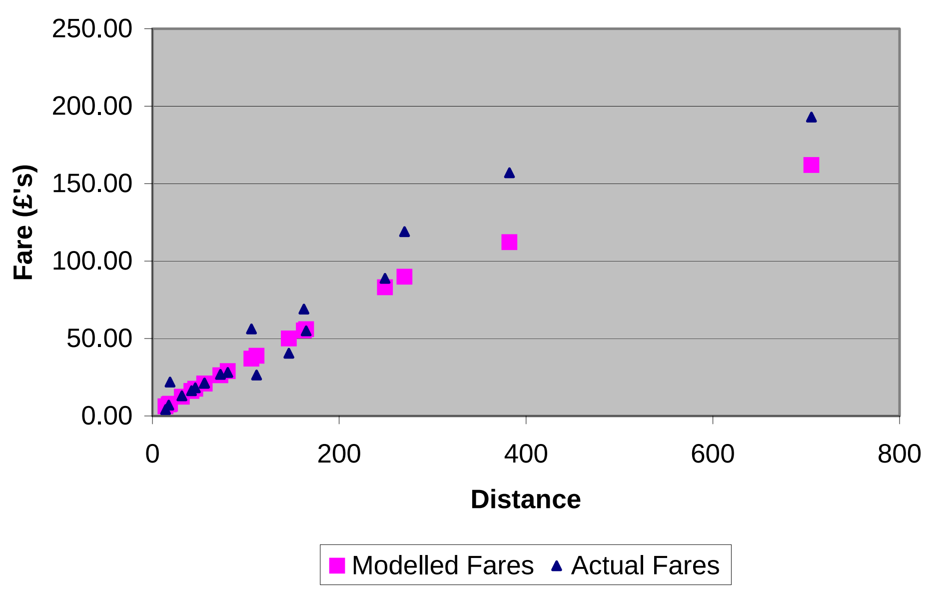
Table 6.1 National Rail Model: Fare Relationships

Ticket Type / Distance Band	'A' Coefficient	'B' Coefficient	R^2
Full Fare			
0 to 50 km	0.3532	1.2825	0.95
50 to 300 km	0.3229	2.7922	0.80
300 km +	0.1533	53.6860	0.75
Reduced Fare			
0 to 50 km	0.1884	1.0918	0.83
50 to 300 km	0.1499	3.0131	0.64
300 km +	0.0722	26.3220	0.57
Season Fare			
0 to 50 km	0.1979	1.5208	0.90
50 to 300 km	0.1102	5.8986	0.72
300 km +	0.0000	38.9490	-

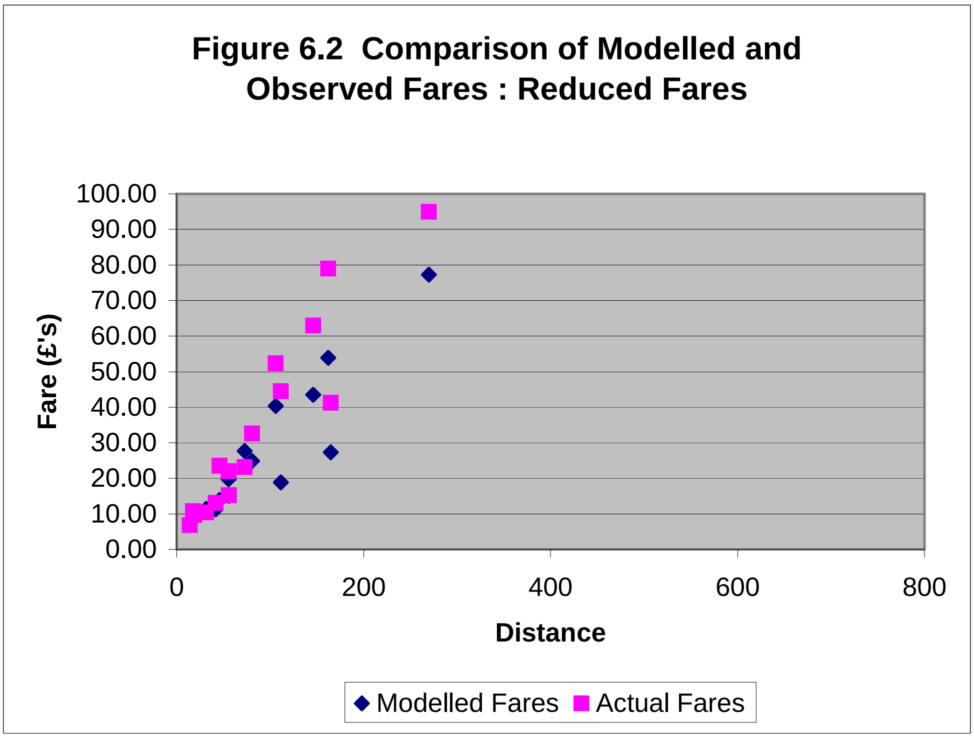
Note:
Equation is Fare = A * distance + B

Figures 6.1 to 6.3 show the comparisons of modelled and actual fares for the three ticket types.

Figure 6.1 Comparison of Modelled and Observed Fares : Full Fare



The figures show that for all ticket types with journeys under 50km the actual fares correspond closely to those being modelled. The model is reasonably accurate for journey length up to 300km, but decline in accuracy due to the crow fly distance not corresponding very well with the actual rail distance. With the majority of the rail trips being made over distances of less than 300 km, the current distance based fare calculation method is considered adequate.



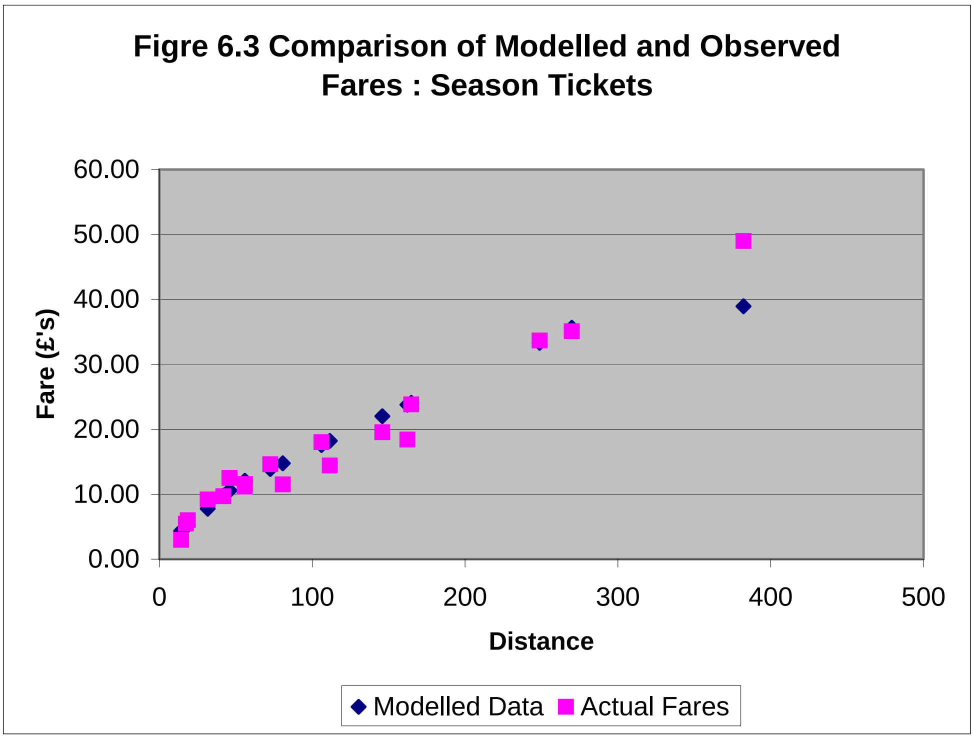
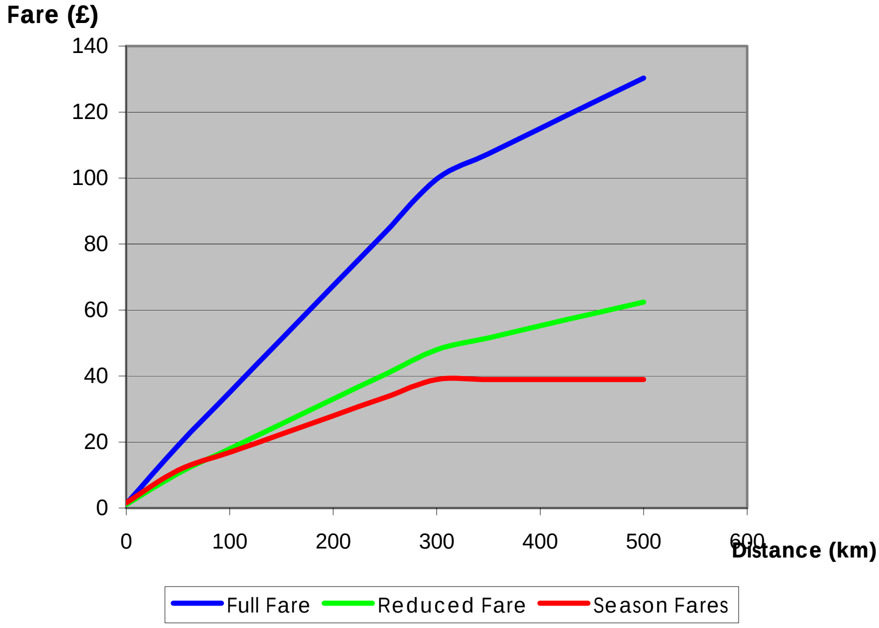


Figure 6.4 shows the actual fare relationships used in the model, for the three ticket types.

Figure 6.4 - National Rail Model Fare Structure by ticket type and distance band



6.3 LONDON UNDERGROUND

The London Underground six zone based fare structure required a more complex methodology than that used on the National Rail distance based structure in order to create an appropriate fare matrix. This zone based structure means that fares do not have a direct relationship with distance travelled. Consequently to develop an appropriate fare matrix the six zone fare structure was modified by splitting zones 2 to 6 into 4 further segments, giving a disaggregated zone system totalling 22 zones, Figure 6.5. Zone 1 remains unchanged and zone 22 represents those zones outside of zone 6. By dividing the area in this way it is possible to represent the movements within London in terms of the number of zones that are traversed.

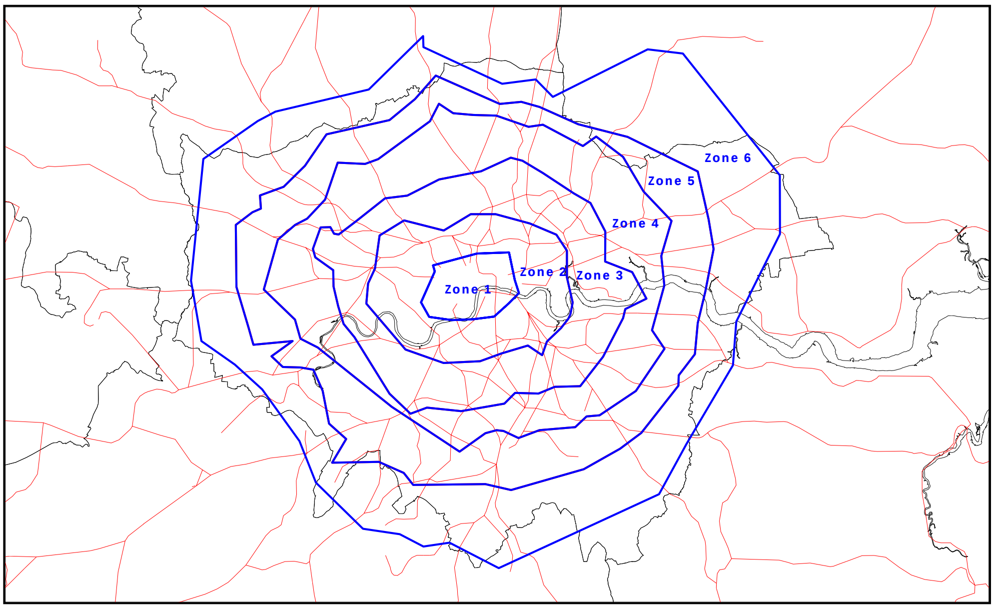
The zone structure was created by tagging all the centroids within each disaggregated LUL zone. Using this information a sub-matrix is defined at the 22 zone level from which the fares for each movement can be allocated from a look up table. The model can then determine the LU fare for each DRNM zone to zone movement. In order to determine the appropriate fare eleven fare combinations are defined as follows:

- Fare for journeys inside Zone 1only
- Fare for a one zone journey between Zones 2 to 6 not via Zone 1
- Fare for a two zone journey between Zones 2 to 6 not via Zone 1
- Fare for a three zone journey between Zones 2 to 6 not via Zone 1
- Fare for journeys between Zones 1 and 2
- Fare for four zone journeys between Zones 2 to 6 not via Zone 1
- Fare for journeys between 1,2 and 3
- Fare for journeys between 1,2,3 and 4
- Fare for journeys between 1,2,3,4 and 5

- Fare for journeys between 1,2,3,4,5 and 6
- Fare for a five zone journey between zones 2 and 6 not via Zone 1

A validation of the LUL fares was undertaken to ensure that the outputs were as expected by running the model and extracting fares for a number of movements. All actual fares were taken from the www.tube.com and relate to those in Summer 2001. They also represent the actual fare for the journey converted into daily, single prices. The validation showed that in all cases the fare was accurately represented in the model.

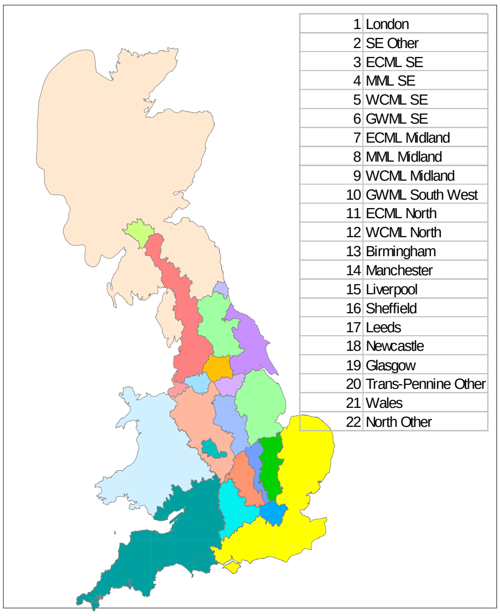
Figure 6.5 London Underground Fares : Zonal Structure



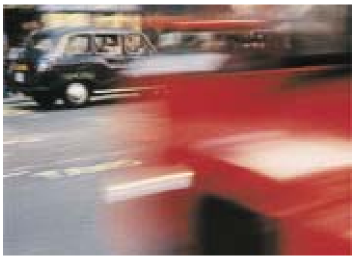
6.4 FARE CHANGES

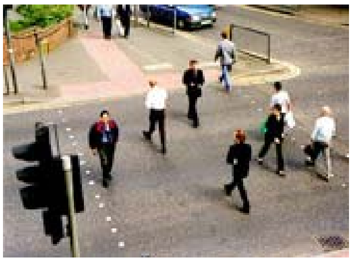
The model contains a mechanism for amending the fares by geographical movement and this is operated through the rail policy user interface. The fare matrix has been segmented as shown in Figure 6.6 and the fare for any movement can be increased or decreased as required in order to test the effect of different fare policies.

Figure 6.6 National Sector Segmentation for Fares Modelling



7 MODEL OUTPUTS





7 Model Outputs

7.1 STRUCTURED OUTPUTS

Main model results are produced automatically for:

- Model parameters used in the run and reports global network statistics for each loop of the iterative procedure;
- Time and cost attributes from the DRNM for input to Pass1;
- Fares by ticket type from the DRNM for input to Pass1;
- Statistics of passenger–km's segmented by corridor and area type;
- The crowded and un-crowded passenger-hours separately along with the PIXC indicators for London-bound commuting services; and
- Train emissions by area.

The rest of this Section describes each of the output files respectively.

7.1.1 Model Parameters and Run Time Statistics

This text file is produced at the end of each model run and reports model parameters used for the run and network statistics for each loop of the iterative process.

7.1.2 PASS1 Time and Cost Inputs

This text file is produced at the end of each model run and saved in the subdirectory **PASS1OUT,** and can be imported into Pass1 for the next stage of the modelling process. It contains the following data information:

Column Number	Description
1	Origin area type (1 to 15)
2	Destination area type (1 to 15)
3	Distance band (1 to 13)
4	Period (1for AM, and 2 for IP)
5	Access time (min)
6	Wait time (min)
7	Inter-connection time (min)
8	Timetabled in-vehicle time (min)
9	Egress time (min)
10	Crowding penalty (min)

The information in this file can also be used for further detailed analysis.

7.1.3 Fare Inputs to Pass1

This text file is produced at the end of each model run and saved in the subdirectory **PASS1OUT**, and can be imported into Pass1 for the next stage of the modelling process. It contains the fares assumptions used in the model run. The information is organised as follows:

Column Number	Description
1	Origin area type (1 to 15)
2	Destination area type (1 to 15)
3	Distance band (1 to 13)
4	Average fares for commuting purposes
5	Average fares for business purposes
6	Average fares for leisure purposes

7.1.4 Annualisation Factors

At present time there are two separate annualisation factors in use in the presentation of annualized outputs of the model. The first figure converts daily passenger related information, numbers and kilometers, to annual values and takes a value of 330. This factor has been derived from the assumption that there are 250 full working weekdays and 114 weekend days/public holidays per year. It is further assumed that the volume of travel on weekend days and public holidays is 70% of that which occurs on a full working weekday. Application of these values calibrates well with the information provided by the train operating companies.

The second factor used relates to train kilometers run and is 9% higher at 360, than the passenger related factor. The higher annualisation factor accounts for lost/dead mileage and also adjusts for any inevitable network coding simplifications of the all day timetable. This value also calibrates well against train operating company information.

7.1.5 Passenger Km Statistics

Presents statistics of passenger–kms segmented by corridor and area type.

7.1.6 Passenger Hours

Information on passenger–hours, segmented by corridor, is presented separately for crowded and un-crowded passenger-hours. The latest version of the spreadsheet file also reports PIXC indicators for London-bound commuting services.

7.1.7 EMISSIONS

Emissions are modelled using NRM output on train-km combined with appropriate emissions factors.

The emissions considered include:

- carbon
- carbon dioxide
- NOX
- particulates (PM10)

- sulphur dioxide
- carbon monoxide

For the 10YP emissions were modelled from a passenger km base, requiring judgments to be made about how load factors change. The NRM has been designed to address levels of crowding, therefore, it can provide information directly on train kilometres obviating the need to consider load factors in the emissions model (although future year services still have to be specified drawing on SRA information). Thus the factors of interest are at the train kilometre level - although in many cases the emission factor is stated at the level of the individual car.

Each transit line has been allocated a specific emission category according to its vehicle type coded in the network model. Emissions are then calculated taking account of the service characteristics of vehicle type, frequency, car per train, and peak/inter-peak period, etc.

The tables produced for emissions include:

- Annual train-kilometers by corridor, area and period;
- Total annual emissions by period (ie peak and inter peak periods) and pollutant type;
- Total annual emissions by corridor, area and pollutant type;

- Emissions by area type (ie London, Metropolitan/Large Urban areas and Urban/Rural areas) and period.

Figures of train-kilometres have been calibrated to 2000 level, based on SRA's annual statistics. Please note that the peak period covers 6 hours (ie 3 hours for AM peak and another 3 hours for PM peak). The inter-peak period covers 6 hours 10:00-16:00. These are calculated based on service frequency in the AM and Inter-peak network models.

7.2 USER DEFINED

As the model is held in EMME/2 the experienced user, with EMME/2 expertise, can extract a vast amount of detailed information on the model results. This can include individual service loading patterns by time period, corridor flows by time period, and boarding and alighting figures for individual or groups of stations.

7.3 LINKAGE TO TUBA

Overview

One aspect of the study is to identify an appropriate TUBA interface for the Department's National Rail Model tests. This paper explains the specification for TUBA runs, including attributes (EMME/2 matrices) to be imported, market segments, model periods, matrix requirements, number of zones/sectors and interface forms.

Attributes to be imported

Three attributes are needed:

- Rail trips;
- Rail journey times (un-weighted sum of access/egress time, waiting time, boarding time, and un-crowded in-vehicle-time.); and
- Rail fares.

Market segments

- Business;
- Commuting; and
- Leisure.

Peak periods

- AM peak period (7:00am – 10:00am); and
- Inter-peak period (10:00am – 16:00pm).

Factors are to be developed to convert TEE table results from AM and inter-peak periods to daily and then annual figures.

Matrix Requirements

For TUBA analysis of the modelled output, the following 18 matrices will be required for each modelled year (note that public transport TUBA analyses do not require distance matrices):

Table 7.1 TUBA Input Matrices

	AM peak period	Inter peak period
Trips	Commuter trips Leisure trips Discounted trips	Commuter trips Leisure trips Discounted trips
Journey Times	Commuter time Leisure time Discounted time	Commuter time Leisure time Discounted time
Fares	Commuter fares Leisure fares Discounted fares	Commuter fares Leisure fares Discounted fares

A simple test with a do nothing and a do something scenario will therefore require 36 (2x18) matrices.

Run Times

The NRPM has 1318 zones. FaberMaunsell has previous experience of TUBA and runtimes seem to increase exponentially as the number of zones analysed increases. The number of zones in the NRPM will cause long TUBA runtimes, and so an alternative sectoring system may be required.

The TUBA analysis used for the Cambridge to Huntingdon Multi-Modal Study (CHUMMS) illustrates this issue of runtimes. In CHUMMS, a 201-zone TUBA analysis had runtimes of 10 minutes for a 22-sector analysis, and 4 hours for a 201-zone analysis. An estimate of TUBA runtimes for the NRPM without sectoring would be anything upwards of 10 hours. A reasonable sectoring system may therefore need to be tested and then decided to achieve both run time efficiency and also retaining a satisfactory degree of details.

Interface

TUBA can easily accommodate 36 matrices with each in a separate file. This would allow the use of Format 2 matrices (Origin, Destination, Trips). However, to provide flexibility for further user-classes or for multiple modelled years, Format 3 matrices are more appropriate (Origin, Destination, User-Class, Trips).

A visual basic based programme can be developed to convert matrices from EMME/2 format to TUBA format automatically.

It is envisaged that a spreadsheet file can be developed to import TEE table results, skim off redundant information, and present figures in formats to be agreed with the Department.