Rail Research UK

Report C3/3

Demand Modelling Proposals

Prepared for Rail Research UK
by

Tony Fowkes, Daniel Johnson, Chris Nash, Gerard Whelan and Tony Whiteing
(Institute for Transport Studies, University of Leeds)

Project C3: Role of Rail in Integrated Transport Policies

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Abstract

This report is prepared as part of the RRUK project 'The Role of Rail in Integrated Transport Policies'. This project seeks to shed light on the appropriateness of the alternative future rail strategies presented in RRUK Report C3/2 'Rail/Road Strategies and External Scenarios' by modelling their impacts. The report sets out the requirements for the modelling framework and reviews the suitability of existing rail demand models to the task. For passenger traffic these included:

- The Passenger Demand Forecasting Handbook (PDFH);
- The Framework Model (RIFF);
- MOIRA;
- The Lythgoe Model;
- PRAISE;
- The National Rail Model; and
- PLANET.

And for freight traffic these included:

- GB Freight Model (GBFM) (MDS Transmodal);
- EUNET Model (TransPennine Model);
- SKM 'Additional Freight Model';
- SRA Freight Interchange (CAST-DPM) Model; and
- The LEFT model.

For the passenger sector, a new model is proposed which brings together the relative strengths of the aggregate direct demand models (PDFH, RIFF, MOIRA and the Lythgoe Model) where the vast majority of rail demand research has been undertaken. For the freight sector, two models are selected. The LEFT model, currently under development at ITS, looks very suitable for the work in this project, but it needs further development and testing. As a more well established alternative, and for more details policy tests, the GBFM model is recommended. This is available to ITS for research purposes.

1 Introduction

This report has been prepared as part of the RRUK project 'Role of Rail in Integrated Transport Policy'. This project seeks to shed light on the appropriateness of alternative future rail strategies by modelling their impacts. The objectives of Project C3 are to:

(a) Identify alternative aspirations for the future of rail in an integrated transport policy;
(b) Understand capabilities of existing models to forecast such changes;
(c) Identify appropriate model developments for this purpose;
(d) Enhance existing models to enable appraisal of alternative aspirations; and
(e) To consider the implications of the appraisal results for future rail research needs.

It is the aim of this report to address objectives (b) and (c) by undertaking a review of the rail demand models currently used in Britain to assess how they may be adapted to help answer the policy questions relevant to this project. Objective (a) is covered in RRUK Report C3/2 and objectives (d) and (e) will be addressed in the second and third years of the project. The report deals first with passenger modelling and then freight.

2 Passenger Modelling Requirements

2.1 Introduction

Forecasting the demand for rail services is an essential part of the planning process. Forecasts are important to ensure that the right services are offered at the right time and at the right price. To do this effectively, models are required to predict background changes to rail demand and to examine the influence on demand of changes to rail policy. Over the long term forecasts are required for strategic organisation and major investment decisions, in the medium term they are required for franchise planning and in the short term they are required to test fare and service level options. In this project we are primarily focusing on the strategic issues set out below.

2.2 Scenarios and Policy Options

RRUK Report C3/2 identified a number of alternative future policy and scenario options for which it would be appropriate to examine using a rail demand model. The policies include three alternative strategies for rail and three strategies for road, and the scenarios include three levels of macro-economic performance.

With regard to rail, the three strategies include an investment strategy commensurate with the Ten Year Plan, an investment strategy involving a rationalisation of rail services and an investment strategy involving significant freight and passenger service upgrade. More specifically, rationalisation might involve a widespread reduction of the rural rail network infrastructure; a widespread reduction in rural services; a reduction in regional services during the off-peak and implementation of bus substitution; rationalisation of freight services; retention of peak commuter services into key urban areas, e.g. Birmingham, Manchester, Leeds etc; development of commuter services in the south east; and development of intercity services.

The passenger upgrade might involve higher frequencies and speeds; development of new services to fill gaps in the network; introduction of national regular interval timetables with improved connections; simplification of fare structure; improved integration between transport modes; a new high speed line; schemes to tackle strategic bottlenecks on the rail network, including those in the West Midlands and in the Manchester commuter area; electrification of core routes; and selective re-openings (e.g. Matlock-Buxton).

With regard to the specification of alternative road strategies, these include a strategy in which all road investment is as specified in the Department for Transport's Ten Year Plan; a strategy based on demand management by urban and inter-urban road pricing; and a strategy based on doubling road investment.

The combination of the alternate road and rail strategies generates nine policy options that when combined with three different macro-economy scenarios generate 27 situations to be modelled and assessed, although, as outlined in RRUK Report C3/2, we expect to concentrate on a subset of these.

2.3 Model Selection

In choosing an appropriate modelling framework it is important to consider the use to which it will be put, the level of detail required to provide meaningful results, the required inputs and outputs, and the cost and practicality of developing the framework.

To address the issues set out in Section 2.2 the passenger modelling requires a high degree of disaggregation. It is important to represent spatial issues so that modelling can incorporate changes in access through changes to network size and route structure. In many instances it will be sufficient to model changes in demand for an existing set of services, however where network size and route structure change it is likely that the modelling framework will need to generate absolute demand forecasts. This is considerably more difficult. To accommodate changes in passenger crowding it would be useful to model fluctuations in demand by time of day or ticket type, and to facilitate an assessment of the distribution of costs and benefits it would be useful to include details of key market segments (e.g. journey purpose).

It is useful to include variables that are relevant in explaining passenger behaviour and those that are geared towards policy testing. To this end likely variables include: sensitivity to changes to fares, service quality, passenger-crowding, external factors (GDP, car ownership and socio-demographics), and the capability of assessing changes to the competitive position of road (car and bus) and air.

The model inputs and outputs are determined by the required level of aggregation and the range of explanatory variables. There are however likely to be constraints on the type and quality of the data available for modelling and on the availability of suitable forecasts of explanatory variables over potentially long forecasting horizons. There are well documented problems with ticket sales data providing information on revenues and flows. Arguably the most important of these is the lack of detailed information of Travelcard usage within London and the metropolitan areas. This makes modelling important urban commuter flows difficult. As a minimum the model should provide forecasts on rail demand and revenue at an appropriate level of aggregation, however other outputs such as modal shift would be useful for appraisal.

The demand response to the sorts of policy changes suggested in Section 2.2 are likely to be non-marginal and be spread over a long time horizon (up to 30 years). This feature has implications for the choice of model form and in particular the use of constant or variable elasticities of demand.

Finally, it is important that the models can be built and applied in a way that is practical and affordable and that they can be validated to ensure a degree of credibility.

3 Review of Passenger Models

3.1 Introduction

Compared to the wealth of methodologies developed and applied to forecasting road passenger traffic there is a relatively small literature of forecasting the demand for passenger rail services. Within this area three broad types of methodology exist:

- Aggregate direct demand models;
- Disaggregate choice models; and
- Mode choice and assignment models.

It is the aim of this section of the report to describe the main features of each methodology and provide examples of their use in Britain. Appendix 1 of this report provides additional details of each of the modelling approaches discussed.

3.2 Aggregate Direct Demand and Elasticity Models

The rail industry records information on demand and revenue by ticket type across all flows on the network. This data forms an excellent starting point for the development of aggregate econometric models of rail demand. This section provides an overview of the use of aggregate demand data together with details of four commonly applied aggregate demand modelling methodologies, including: the Passenger Demand Forecasting Handbook (PDFH), the Framework Model, MOIRA, and the Lythgoe Model. There are, of course, other aggregate demand models that we are aware of but these have either fallen by the wayside (e.g. MONICA) or have been developed by consultancies for their own forecasting needs (e.g. the OXERA model).

3.2.1 Aggregate Demand Model Overview

The method relates the demand for rail travel between two stations in a given period (the dependent variable) to a vector of explanatory variables whose influence on demand is described by a set of model parameters. These parameters and their variance are sometimes estimated directly using regression analysis or are sometimes adopted and constrained to be equal to parameters estimated elsewhere. The latter approach is extensively used in the application of elasticities of demand. The precise functional form of the demand expression varies from study to study but it is possible to identify a range of commonly used explanatory variables, including:

- *Rail fares* – derived from fares manuals or more commonly average revenue estimates;
- *Timetable related service quality* – derived from timetables and includes in-vehicle time, service frequency, interchange requirement and connection time;
- *Access and egress times* – derived from analysis of cross sectional data in the definition of station catchment areas;
- *Rolling stock quality* – the ‘unpacking’ of rolling stock quality attributes such as comfort, ride quality, cleanliness, availability of toilets, telephones etc. is

usually obtained through market research whereas the total effect can be assessed using aggregate ticket sales data;
- *Performance* - punctuality and reliability indices derived from published sources;
- *Competition* – the influence of the price and quality of competing modes of transport (car, bus, coach, air);
- *Exogenous factors* – the influence of changes in population demographics, income (GDP) and car ownership on rail demand;
- *Time trend* - to account for other secular trends; and
- *Dummy variables* – to account for seasonality or other shocks to the system (e.g. rail privatisation).

3.2.2 Inventory of Aggregate Demand Models

Four of the most commonly applied aggregate demand models are discussed below.

(i) The Passenger Demand Forecasting Handbook
The Passenger Demand Forecasting Handbook (PDFH) summarises knowledge of effects of service quality, fares and external factors on rail passenger demand and provides guidance on applying this knowledge to the preparation of forecasts for investment and service planning. Its applications include investment appraisal, marketing and planning, budgeting and assessing customer response to timetabling and operating decisions.

The Handbook is maintained by the Association of Train Operating Companies (ATOC) and is intended for use by participants and associate members of the Passenger Demand Forecasting Council. Forerunners to the latest edition (PDFH Version 4, 2002) include ‘British Rail Passenger Forecasts’ issued in June 1982 and the first three editions of PDFH issued in 1986, 1989, 1994/1997.

The PDFH recommends a framework for the application of elasticities of demand and rail attribute valuation to facilitate forecasts of the aggregate demand response to changes in:

- the external environment (e.g. GDP, car ownership, employment, cross modal competition);
- fares;
- journey time, service frequency and interchange;
- reliability and punctuality;
- non-timetable related service quality (e.g. rolling stock quality, crowding);
- new services and station access; and
- competition between operators.

For each of these factors, the PDFH provides a theoretical background, a mathematical framework, a set of recommended values, simple and more complex forecasting and applications. Details of this approach are set out in Appendix 1.

(ii) The Framework Model (RIFF)

The Rail Industry Forecasting Framework (RIFF) was developed by consultants Steer Davies Gleave to improve the procedures for providing passenger rail demand forecasts. The model is based on elasticities and attribute-values from a wide variety of different areas, including the PDFH, a review of other literature, fresh survey work, theoretical relationships and new econometric analysis. The emphasis of the model is on the effect of external factors on rail demand. These external factors include the economy, socio-demographics and competition from other modes.

The key demand drivers are similar to those identified in PDFH3 but are adapted to take better account of the influence of changes in GDP on rail demand by journey purpose and to identify the contribution that changes in car ownership and road congestion have on rail demand. The results of RIFF were used to inform further analysis of these issues in PDFH4.

(iii) MOIRA

MOIRA is a system for producing demand and revenue forecasts. It is owned and maintained by AEAT and it is widely used by the majority of Train Operating Companies (TOCs) and the Strategic Rail Authority. MOIRA uses the same basic methodology as outlined in the PDFH but augments provides software to calculate changes in generalised journey time and consequently demand for all O/D pairs following a timetable change, and augments this procedure with a facility to allocate ticket revenue between competing TOCs based on ORCATS[1] routines. Forecasts of passenger demand are based on estimates of changes to the generalised journey time (GJT) using a set of GJT elasticities that vary across routes and ticket type (full, reduced and season). Demand and revenue are allocated to timetabled services using a 'rooftop' model with assumed passenger departure time profiles. Although MOIRA is extensively used to evaluate the revenue implications of changes to timetables it does not include fares within the model. In addition to generating demand forecasts MOIRA can generate estimates of the individual elements in GJT including in-vehicle time, frequency penalty and interchange penalty from timetable data.

(iv) The Lythgoe Model

The Lythgoe model is an aggregate demand model centred on the specification of station catchment areas and competition between stations. The model forecasts the aggregate share of traffic travelling from a given origin zone to a given destination station via a given origin station as a function of:

- Fare and timetable related service quality of competing origin stations to the destination station. This includes measures of regularity, clockfaceness and memorability;
- Population in zones around origin and destination stations;
- Access times and distances from origin population zones to origin and competitor origin stations;
- Egress times and distances from destination and competitor destination stations to destination population zones; and

[1] Operational Research Computer Allocation of Ticket Sales – the system which is used to divide ticket revenues amongst operators where they offer potentially competing routes/services.

- Quality and cost of competing car travel.

The model has a cross-nested logit structure which allocated the share of total rail demand between competing origin station and allows the overall size of the rail market to expand or contract as rail fares and quality of service change.

3.3 Disaggregate Demand Models

3.3.1 Disaggregate Demand Model Overview

Over the last 30 years and over the last 10 years in particular there has been increased interest in developing models of individual choice and demand rather than forecasting collective behaviour such as market shares of travel flows. In making a choice, the individual expresses a preference amongst a set of alternatives which can be explained by their socio-economic characteristics and the attributes of the choice alternatives. The advantages of disaggregate approaches include their ability to avoid an aggregation bias and they are thought to have better theoretical foundations based on the economic theory of the consumer. The models aim to explain causality rather than simply capture correlations. Disaggregate models are relatively easy to calibrate to either revealed preference (RP) data, stated preference (SP) data or a combination of both. RP data includes the choices that individuals make in reality whereas SP data relates to individual's responses to hypothetical questioning. Disaggregate modelling techniques are widely used to provide relative attribute valuations such as the value of time as well as to generate forecasts of individual behaviour.

3.3.2 Inventory of Disaggregate Demand Models

There have been many disaggregate demand models calibrated to provide rail attribute valuations and demand forecasts but by and large these have always been tailored to a specific task or set of circumstances, and are therefore not readily transferable to other situations. An exception to this is the PRAISE (Privatised Rail Services) model which was developed at the Institute for Transport Studies, University of Leeds to look at the potential for open access competition following the privatisation of rail services. The model was initially developed to assess competition on the Leeds to London corridor but it has subsequently been applied to other routes in the UK (Gatwick Express) and overseas (Stockholm to Gothenburg). More recently, the model has been re-written and developed on behalf of the Strategic Rail Authority as a Windows software package capable of assessing demand and costs for small networks of stations incorporating the services of up to 5 operators, each with 10 different ticket types. The software comprises a demand model, a cost model and an evaluation model.

The demand model has a hierarchical structure and works at the level of the individual traveller. Using information on passenger's valuation of journey attributes, such as journey time, together with elasticity estimates, the lower level of the model assigns a probability that a given traveller will choose a particular ticket and outward and return service combination. By aggregating the ticket and service probabilities over a representative set of simulated passengers, the model is able to forecast market shares for each service and ticket combination. To allow for the fact that changing fares and services will change the overall demand for rail, the upper level of the model is structured to allow the rail market to expand or contract according to the overall level of service. By assessing the outward and return portions of a journey, together with information on ticketing restrictions (departure time, advanced purchase, transferability between operators), the model is able to forecast ticket revenue by operator.

The cost model employs a cost accounting approach incorporating, costs that are related to operating hours, costs that are related to train kilometres and fixed costs. Costs can be varied by operator and rolling stock type and can be combined with estimates of revenue to generate forecasts of operator profitability.

The model generates output that can be used in a formal appraisal system. This output includes, passenger demand, passenger distance, operator revenue, operator costs, profitability, user benefits (consumer surplus), overcrowding, and diversion to and from other modes in terms of passenger numbers and passenger distance.

3.4 Mode Choice and Assignment Models

3.4.1 Mode Choice and Assignment Model Overview

The final group of models in common use are mode choice and assignment models. These models typically estimate changes to base demand using either aggregate multi-modal choice models or aggregate elasticity model based on generalised cost or generalised journey time. The forecast demand is then assigned to the network of services using a standard assignment routine which works on the basis of a hierarchy of optimal passenger strategies to transverse the network. The main models to adopt this approach are the National Rail Model and the PLANET Suite.

3.4.2 Inventory of Assignment Models

The National Rail Model (NRM) was developed by FaberMaunsell on behalf of the Department for Transport as part of the Department's multi-modal modelling capability. The NRM is a strategic model covering all national rail and London Underground stations. The model works in an iterative way moving through a number of key sub-models, the most important being a mode choice model and a trip assignment model. The mode choice model generates a multi-modal trip matrix based on modal costs and this matrix is then passed to the EMME/2 assignment package which loads a passenger demand matrix to a network of rail services in an iterative way taking account of capacity and crowding constraints. This assignment is based on the concept of optimal strategies whereby passengers choose a set of paths through the network and board the first train to arrive at their destination. There is no individual based choice mechanism - the algorithm identifies a set of attractive alternatives and then distributes the demand amongst the attractive routes.

The main features of the model include:

- a detailed representation of the network and service patterns for both morning peak and inter-peak periods;

- rail demand and network models were calibrated against observed rail demands by conurbation and main corridor;
- multi-modal functionality based on generalised cost of travel;
- a public transport assignment process including a crowding time element to reflect overcrowding.
- Rail Policy User interfaces to specify various scenarios;
- Model outputs include passenger kilometres, passenger hours, crowding indicators and emissions categorised by corridor and area type; and
- The model also produces outputs which can be used in formal economic appraisal frameworks.

The PLANET Suite of models is similar to the National Rail Model in that it is based on the EMME/2 network assignment package. The model was originally commissioned by British Rail based on the 1991 National Rail Timetable but has subsequently been developed by Jacobs and Atkins on behalf of the Strategic Rail Authority. Briefly, the model works by assigning a base demand matrix to the network taking account of capacity constraints before estimating base generalised journey time matrices which are passed to an elasticity model to estimate the demand impact of changes to the network. The revised demand matrix is then passed back to the assignment model to be loaded onto the network to generate estimates of passenger kilometres, total passenger hours, un-crowded passenger hours, crowded passenger hours, passenger boardings and train kilometres. These are presented by mode and by rail/underground service groupings. Recently, sensitivity to fares and GDP have been added to the model.

3.5 Suitability of Existing Passenger Models

Table 1 shows the extent to which each of the reviewed models meets the modelling requirements set out in Section 2. The table shows the range of explanatory variables included within each model, details of their functional form and an indication of whether they would be available for use for RRUK research.

Table 1: Model Capabilities

		MOIRA	RIFF	PDFH	LYTHGOE	NRM	PLANET	PRAISE
Variables	Fares	No	Yes	Yes	Yes	Yes	Yes	Yes
	Timetable	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Crowding	No	Yes	Yes	No	Yes	Yes	Yes
	External	No	Yes	Yes	No	Yes	Yes	No
	Cross-Modal	No	Yes	Yes	Yes	Yes	Yes	No
Function	Forecasts	Incremental	Incremental	Incremental	Absolute	Absolute	Incremental	Incremental
	Elasticity	Constant	Constant	Constant	Variable	Variable	Variable	Variable
Suitable		No	No	No	No	Yes	Yes	No
Available		No	No	Yes	Yes	No	No	Yes

- Although *MOIRA* is the industry standard it is not suitable for this project since it deals only with marginal timetable changes and does not include fares, crowding, cross modal competition and external growth. It is unable to deal with changes to network size and is only be available for a fee.
- *RIFF* is an aggregate elasticity model that deals with external factors and marginal changes to fares and timetables. The model is unable to forecast absolute levels of demand, contains many constant elasticities and is not available for use on this project.
- The *PDFH* is a collection of the best available evidence on the factors that influence the demand for rail travel. The forecasting framework is however based on incremental changes to existing fares, levels of service and external factors and based largely on constant elasticities. This framework is not suitable for the estimation of changes in demand following changes to network size or large changes to explanatory variables.
- The *Lythgoe Model* has many attractive features in that it is able to deal with access/egress and station choice. However, it has limited functionality with regard to crowding, external factors and cross-modal competition.
- The *National Rail Model* contains all of the elements required for this project. The drawback however is that it relies on the National Transport Model which is formed from a number of sub-models. Adopting the National Rail Model for this project would therefore be too complex even if it were possible to get access to it.
- The *PLANET* Strategic model has much of the functionality that we require but like the National Rail Model, its complexity restricts its suitability for use on this project.
- The very detailed approach offered by *PRAISE* is suited to short run analysis of service load factors, crowding and ticket type choice but this complexity is not suitable for assessing strategic, large scale changes across different modes over the long run.

The models in Table 1 each have advantages and disadvantages. Those which are thought to be suitable for the strategic nature of the modelling task in hand are not available within the resources of this project. The challenge therefore is to make the best use of the information available to us, specifically PDFH, but apply it in a way which generate added value. Details to the recommended approach are set out in the next section.

4 Passenger Model Development

The rail passenger models reviewed in Section 3 represent the most widely applied approaches to demand forecasting in Britain. Although each model has its own particular set of advantages and is suited to specific modelling tasks, they either do not contain the right set of explanatory variables, have an inappropriate functional form or are too complex to be of practical use here. The range of modelling requirements and flexibility needed for this project therefore warrant the development of a new forecasting framework which brings together the advantages of the individual models and maintains sufficient flexibility to examine a broad range of policy tests. It is, however, unlikely that a single model will be capable of addressing all of the policy issues identified and therefore it will be necessary to draw on the findings of existing research.

An outline for the new model structure is set out in Appendix 3. This model has an aggregate direct demand structure centred on inter-urban traffic. It is to be calibrated for a set of flow categories to up-to-date data on ticket sales, service quality and data from the 2001 Census. The majority of the coefficients for the model will be taken from the rail industry's Passenger Demand Forecasting Handbook and will include sensitivity to the following variables: fares (full, reduced, season), rail service quality (journey time, service frequency, interchange), cross-modal competition, station access and egress together with socio-demographic variables such as household income, car ownership, employment and population.

There are a number of advantages in developing this new modelling framework:

- We can calibrate the model to up-to-date demand, service level, and socio-demographic data to ensure that the models represent market conditions for the base period;
- We can draw on the range of tried and tested evidence available to the industry;
- We can include all of the explanatory variables required and test for the significance of new variables;
- We can provide a validation of the model forecasts and examine the sensitivity of forecasts to a range of functional forms which allow for variation in demand response across different markets and over time; and
- We can develop an application tool which forecasts demand for individual flows taking account of changes to rail service quality as well as changes to the socio-demographic characteristics of the station catchment areas, which we believe will be a significant driver of rail demand.

The new modelling framework has considerable flexibility and is suited to application to the majority of required policy tests however additional review work will be needed to look at policies centred on urban rail network and those which involve significant passenger route switching.

5 Freight Modelling

5.1 Introduction

This section starts with a brief statement of the reasons why we might want to model freight transport flows in Great Britain, focusing primarily on aspects of relevance to rail freight (i.e. modelling of rail freight traffic, modelling of modal choice involving rail). It then identifies the limited number of models that have been developed, tested and applied for these purposes in recent years, and evaluates them as to their suitability for further demand modelling exercises, most particularly for strategic modelling of alternative policy scenarios. Various potential enhancements to freight models are also identified and discussed.

5.2 Uses for Freight Transport Models

The Review of Freight Transport Modelling undertaken for the DfT[2] makes it clear that there are two basic uses for demand models:

- to predict likely freight volumes and/or modal shares at various times in the future; and
- to undertake testing of the effects of various influences on the freight market, or of various potential policies that might influence the use of freight transport, either directly (e.g. modal subsidies) or indirectly (e.g. revised regulations on employment conditions).

When considering the value of existing models relating to freight transport, it is assumed that we are interested in **both** of these uses.

Examples of more specific uses of freight models, in the context of this project include:

- to identify the policy scenarios most conducive to growth in rail freight and change in modal choice;
- to test the likely effect on the rail freight market of particular policies that may be introduced (e.g. lorry road user charging);
- to identify the viability of proposed rail freight service offerings;
- to identify potential terminal locations and the likely viability of such terminals; and
- to identify the capability of the network to handle any projected growth in rail freight traffic.

[2] ME&P (2002), *Review of Freight Modelling*. Final Report of Project undertaken for DfT by a study team led by ME&P. Cambridge, ME&P.

5.3 The Need for Detail and Disaggregation

In order to be meaningful, freight modelling must be undertaken at the appropriate level of detail and data disaggregation. There are some aspects for which some disaggregation will generally be needed. Commodity type is one such dimension, though very fine disaggregation is rarely possible here. Other potential disaggregations might include the method of rail freight operation (i.e. trainload, wagonload, intermodal) and length of haul.

The requirement for further disaggregation and detail depends very much on the purpose of the modelling exercise. One such case in point is the need for spatial detail, relating both to the zonal detail for freight generation and attraction and to the network detail. Such detail will be required, for example, if the aim of modelling is to identify particular bottlenecks on networks most in need of capacity enhancement for any given scenario. For a purely strategic appraisal of broad policy options, such network detail is not likely to be required. In the five examples of potential uses outlined above, it might be hypothesised that the need for spatial detail might increase from low to high as we proceed down the list.

Another relevant issue relates to the range of transport modes incorporated into the model. In most cases the emphasis is likely to be on road and rail. If international movements are being considered (which is quite likely) then air and sea transport may also need to be modelled, or at least airports, seaports and the Channel Tunnel may need to be incorporated as places of entry/exit to and from the UK. The increased interest in coastal shipping may call for improved capability to model maritime flows between UK ports.

5.4 What are the Required Model Outputs?

The outputs required from any modelling exercise will depend largely on the reasons for undertaking that exercise. Given that the current stated objectives of government and the rail industry, as set out in the Ten Year Plan, are to increase rail freight by 80% in terms of tonne-kilometres, then there is a clear need for models to produce outputs expressed in physical measures such as tonnes lifted and tonne-kilometres moved.

Other output measures may however also be important. Tonnage-based measures may need to be converted into levels of traffic on the relevant networks. Hence we may need to estimate measures such as gross freight-train kilometres operated or changes in road vehicle kilometres operated, or changes in the various categories of 'sensitive lorry miles'.

It is conceivable that the focus of policy might move away from physical growth in rail freight towards increasing rail's market share. Hence it is important that freight models can produce forecasts of modal shares for the scenarios to which they might be applied.

Emphasis might also be placed on implications for externalities, in which case it will be important to estimate accident impacts or emissions levels, for example.

Other studies will focus on modal choice, i.e. understanding and evaluating the factors that are considered to influence decision-makers with respect to their choice of freight transport mode. In such cases the required model outputs will be rather different, and will focus on the relative valuations placed on the range of factors deemed to be appropriate.

5.5 Inventory of Multimodal Freight Models

There is relatively little history of multimodal freight demand modelling in the UK. For road transport, considerable effort has been expended on the National Road Traffic Forecasting (NRTF) methodology, but (as suggested by the title) this concentrates more or less entirely on road traffic and attention to rail freight is minimal.

There is also a history of paucity of information regarding rail freight flows on which to base any modelling. Rail freight data has tended to be held by the operators, and whilst it has been made available to various studies over the years, it is presented in terms of terminal-to-terminal flows. Origin-destination matrices, showing traffic distributed between a set of zones, have not been compiled. Estimation of such O-D matrices for rail freight has therefore been a significant task facing any organisation attempting to construct a multimodal freight demand model.

The following models have been identified as having been used for multimodal freight modelling in Great Britain in recent years.

- GB Freight Model (GBFM) (MDS Transmodal)
- EUNET Model (TransPennine Model)
- SKM ‘Additional Freight Model’
- SRA Freight Interchange (CAST-DPM) Model.

Whilst these models have generally been produced either for specific purposes or as demonstration projects as part of wider research programmes, they have been used a little more widely since. Some have for example been used to produce freight forecasts in the recent Multimodal Transport Studies, with rather mixed success by all accounts.

More recently, as part of its contribution to the ITeLS project, University of Leeds ITS has begun development and testing of the Leeds Freight Model (the LEFT model). The purpose behind this development is to provide a means of rapid testing of strategic options. The model is as yet in its infancy, but is currently able to estimate the effects of a range of policies on road and rail market shares in Great Britain. Developments in the near future will include the ability to examine changes in the size of the GB (road and rail) freight market in addition to the effects on modal shares.

A short description of each of these models is now presented in tabular format in Appendix 2.

5.6 Key Areas for Future Model Development

It is clear that the freight models discussed in the previous sections suffer from a range of shortcomings. Some of these are inevitable given the scale and complexity of the task, but it is also apparent that a better understanding of the freight market is required before significantly better models can be developed. Having said this, most of the problems relate to the application of models to tasks where relatively high levels of (e.g. spatial) detail are required. For broader testing of strategic policy alternatives the situation is rather more satisfactory. Some of the identified shortcomings are discussed below.

- There is a need for much more accurate and appropriate data on the value density (value per cubic metre) of freight for each commodity type, and also on loading density (volume to weight ratio). In the first case, international trade (Customs & Excise) statistics can allegedly help, because they publish both volume and value trade figures on a quarterly basis. The danger here is that there are variations in value density within commodity types and it cannot be assumed that value densities for international freight will be the same as those for domestic freight. This issue is not so important for the use of models in a more strategic context, because here the need is typically to be able to convert tonnages into vehicle movements (hence value data is not relevant). The issue of volume to weight ratios is more important, because tonnage or tonne-kilometre data needs to be converted into vehicle-kilometres. Tonnes per vehicle will need to be estimated separately for each commodity group.
- For some modelling purposes there is a need to link freight generation and attraction in each model zone more successfully to indicators of economic activity (production and consumption) in those zones. The EUNET model would seem to get closest to this. GBFM does not attempt this at present, though it would no doubt prove possible were resources to be made available. This will be a significant issue if models are to be used to identify priority investment needs on transport networks and if it is expected that economic performance will vary significantly over time between different zones. Again, this problem is less significant if models are to be used in a more strategic context, when a national average expected economic performance may well suffice.
- For some purposes there is a need for much more explicit incorporation of logistics systems used for each commodity. These systems need to be reflected in the likely stages of the supply chain, with transport movements representing the linkages between those separate stages. In this way, the choice of inventory holding locations enters the model in a more explicit way. There have been suggestions as to how to do this, and the EUNET model makes a creditable attempt. Arguably, only relatively crude representations of supply chain operations have been attempted to date. In the case of more strategic use of models, where spatial or zonal effects are not important, it may be sufficient to approximate such supply chain effects through assumptions about changing average lengths of haul or changing volume to weight ratios, for example.
- There is a need to provide a feedback loop so that changes in transport costs on any one mode will impact on total market size rather than solely on modal

shares. The development of the LEFT model, discussed above, will attempt to address this issue.

- There is a need to improve models by using better (and more disaggregated) model parameters. One example would be the use of commodity-specific values of time. As above, it is intended to move towards this approach as the LEFT model undergoes further development.

5.7 Tractability / Ease of Computation of Freight Models

Whilst the enhancements to freight models outlined above would seem to be desirable in many circumstances, they will not be easy to achieve. Obtaining the relevant data is clearly a problem. Additionally, improvements 2 and 3 above expand the size of the model significantly. It is believed that existing models such as EUNET and GBFM are already testing the limits of affordable and readily available PCs. Some potentially useful features of GBFM, for example, are currently switched out in order to reduce run times. Adding more dimensions to the field of study, with consequent requirements for more data and computation, may lead to a need for models to be installed on larger and more powerful computers. This would reduce their portability and potentially restrict their use. This primarily relates to the third of the points above, i.e. the need to incorporate supply chain effects into the model. The existing representations only appear to consider a limited number of supply chain linkages, e.g.

- Materials inputs to production;
- Primary distribution flows (such as from factories to warehouses);
- Secondary distribution flows (depot to retail flows).

Arguably this is insufficient, especially in the light of the growing importance of both:

- International trade flows;
- 'reverse logistics' operations (e.g. removal of packaging for recycling, return of damaged or unwanted goods to depots).

Hence more categories of logistics stages may be required, and there are question marks as to whether these can be accommodated.

Given such problems of data availability and potential model complexity with serious consequences for tractability of use and run time, there is clearly considerable value in simpler models which allow rapid testing of a range of options at a strategic level, but which nevertheless produce cogent results. It is this particular requirement that the LEFT model is attempting to address.

5.8 Suitability for Strategic Modelling of Alternative Policy Scenarios

The MDS Transmodal GBFM model is at present the most readily available to use in a relatively 'off the shelf' format. The model has a fair degree of credibility as a result of its status as the freight module for the DfT's National Transport Model. This has been the subject of investigation and audit within the last year, so further information should be available soon. Whilst the model has a number of shortcomings (some of which may be fixable were suitable work to be commissioned, such as the incorporation of a detailed rail network), these primarily restrict its value in more detailed and disaggregated applications. For use in strategic applications the model's limitations would seem to be less significant.

The EUNET model offers a number of theoretical advantages and is probably the most defensible from a theoretical point of view, given its better definition of the rail network, its attempt at economic Input-Output analysis as the basis of freight generation and attraction and its attempt to represent different stages of the supply chain. The fact that it is large, incorporating passenger and public transport forecasting capabilities as well as freight, is a potential disadvantage. It would appear that any application outside the TransPennine region would require major work on zonal and network coding. Were the whole country to be modelled at the level of detail used for the TransPennine work, the model would become very large indeed. For more strategic applications involving the prediction of national freight market totals or market shares for relatively broad commodity groups and distance bands, EUNET would seem to offer no significant advantages over the more widely tested GBFM model.

Information and documentation is less readily available on the **SKM 'Additional Freight Model'**, and access to the data underlying the model would appear to be subject to strict control.

The SRA's **Freight Interchange (CAST-DPM) Model** was created for the specific purpose of deriving a strategic rail freight terminal network. Its suitability for modelling for other purposes is not particularly clear. The basic model formulation is rather different from the other candidates, being based on depot location software widely used in the logistics industry. This identifies locations either through optimisation or via a heuristic mechanism. The outcome is therefore deterministic rather than stochastic in nature. Moreover, there are strict controls over availability of the underlying data.

The LEFT model is still very much in its infancy and needs to be further developed, fully documented and subjected to rigorous testing before it can be used with confidence for forecasting freight market totals and market shares. The fact that it is being developed specifically for the rapid testing of strategic options means that it could be used as a 'first cut' for analysis in order to pre-select options to be tested more fully, perhaps using the GBFM model. Another potential advantage of the reduced complexity of the model is that it should prove easier to adapt to meet the specific needs of particular research projects (i.e. it is less of a 'black box'). Furthermore, it is the intention to incorporate features that may not be built into other models. Examples mentioned earlier in this report are:

- a feedback loop to ensure that changes in transport costs on any one mode impact on total market size rather than solely on modal shares;
- the use of commodity-specific values of time.

For the purposes of high-level strategic freight modelling, there would seem to be merit in the combined use of the LEFT and GBFM models, perhaps using the former to determine the ‘first cut’ of strategies worthy of further analysis, and also to compare the results from the two models. Such comparison would certainly help to develop and refine the LEFT model, whilst also reducing the dependence on its forecasts until such time as its capabilities have been fully evaluated.

More detailed freight modelling seems likely to remain highly problematic until the various issues set out earlier in this report have been addressed.

6 Conclusions

This report sets out proposals for the modelling of the demand for passenger and freight rail services in the next phase of this project. The proposals arise from a review of the modelling capabilities required to facilitate an assessment of the alternative scenarios presented in RRUK Report C3/2 'Rail/Road Strategies and External Scenarios'. This review assessed the suitability and practicality of making use of existing models. For passenger traffic these included:

- The Passenger Demand Forecasting Handbook (PDFH);
- The Framework Model (RIFF);
- MOIRA;
- The Lythgoe Model;
- PRAISE;
- The National Rail Model; and
- PLANET.

And for freight traffic these included:

- GB Freight Model (GBFM) (MDS Transmodal);
- EUNET Model (TransPennine Model);
- SKM 'Additional Freight Model';
- SRA Freight Interchange (CAST-DPM) Model; and
- The LEFT model.

For the passenger sector, a new model is proposed which brings together the relative strengths of the aggregate direct demand models (PDFH, RIFF, MOIRA and the Lythgoe Model) where the vast majority of rail demand research has been undertaken. For the freight sector, two models are selected. The LEFT model, currently under development at ITS, looks very suitable for the work in this project, but it needs further development and testing. As a more well established alternative, and for more details policy tests, the GBFM model is recommended. This is available to ITS for research purposes.

APPENDIX 1: PASSENGER MODEL INVENTORY

Passenger Demand Forecasting Handbook (PDFH)

Attribute	**Description**
Model name	Passenger Demand Forecasting Handbook (PDFH)
Developed by	The handbook is maintained by the Association of Train Operating Companies (ATOC)
Ownership and availability	PDFH is intended for use by participants and associate members of the Passenger Demand Forecasting Council.
Software	The Handbook is a hard copy set of parameters, values and models, although there is some software, PDFHAT, containing some of the main components of the handbook, which can be used for forecasting. This does not require any other pre-installed components.
Applications to date	Its has been applied widely within the rail sector, including investment appraisal, marketing and planning, budgeting and assessing customer response to timetabling and operating decisions.
Model structure	The PDFH recommends a framework for the application of elasticities of demand and rail attribute valuation to facilitate forecasts of aggregate demand changes.
Basic approach to modelling	The handbook provides specific attributes and values for a range of factors including: • The External Environment • Fares Elasticities • Journey Time/ Frequency/ Interchange • Reliability • Non-timetable related service quality • New services/ access • Competition between operators For each of these factors, the PDFH provides a theoretical background, a mathematical framework, a set of recommended values, simple and more complex forecasting and applications. Recommended values vary in many dimensions, such as journey purpose, ticket type, distance, GDP, income, competition and flow type.
Spatial coverage	The values cover the whole of the GB rail network, with more detail in the South Eastern corridors.

Zoning system	Recommended parameters and elasticities are disaggregated by regions such as • London Travelcard Area • South East • Rest of Country London (by distance band) • Non-London Inter-Urban Flows With/ without Full Set of Tickets, (by distance band) • Airports
Time periods used	The models are based on annual data
Time horizon	The user can compound annual changes to yield forecasts for any desired time horizon.
Inputs	User will have to provide values of variables such as generalised time components, fares, service quality and macro economic factors such as car ownership, GDP, costs and journey times of competing modes.
Model Outputs	Changes to Demand

The Framework Model(RIFF)

Attribute	**Description**
Model name	The Framework Model
Developed by	The model was developed in 2000 by Steer Davies Gleave.
Ownership and availability	SDG
Software	The model is implemented through bespoke software based on an Access Database with an Excel/ Visual Basic front end.
Applications to date	The Rail Industry Forecasting Framework has been used to improve the procedures for providing passenger rail demand forecasts. Results of research into elasticities have been used in PDFH
Model structure	The model is an aggregate direct demand model, based on information on origin and destination zones, flows, track and service network links, elasticities and other calculations. The model is uni-modal, but incorporates the effect of competition from other modes via cross-elasticities
Basic approach to modelling	Demand for year i is estimated based on a set of demand drivers, for which elasticities are required. Also included is the proportional change in demand due to timetable changes, the growth in year due to population changes *and* the residual growth in year *I* to *i+1.* A set of appropriate elasticities are required for each demand driver, differentiated by flow category and trip purpose. Cross mode effects can also be captured using this formulation, if demand drivers are defined describing conditions on competing modes, and cross-mode elasticities are available.
Spatial coverage	The modelling encompasses the whole of the GB rail network
Zoning system	This zoning and degree of aggregation is entirely up to the user and will typically vary by the scope of the case study and the data available.
Time horizon	The model can forecast for whatever time frame the user specifies, but will require estimates of future variables such as population, employment, car ownership and car running cost.

Inputs	The model uses information from existing data sources, including: CAPRI, which provides information on base year flows of passengers and revenues by operator and ticket type. Tickets are broken up into Full, Seasons, Standard Class, Standard Class advanced purchase/ promotional and Miscellaneous • SCORES, which provides information about changes in components of travel time as future time-tables are introduced. • MOIRA, as an alternative source of information on the effects of future service changes.
Policy Variables	Fares and service levels.
Model parameters/Elasticities	The econometric analysis carried out by the Centre for Economics and Business Research (CEBR) as part of this project gives some new evidence on fares elasticities, GDP and population elasticities linked with journey purpose, and car ownership and congestion elasticities which were previously subsumed in a generic time-trend. The model also incorporates some proposed cross-elasticities to the costs and service characteristics of other modes. These have been estimated using the diversion factors approach. Other values proposed are based on PDFH values, other research, or 'best guesses'.
Model Outputs	The model delivers a database of flows between zones, differentiated by: • Origin and destination zones • Ticket category • Trip purpose • Route number • Year • Trips and revenue Other outputs contain service links and rail infrastructure links information

Lythgoe Model

Attribute	**Description**
Model name	The Lythgoe Model
Developed by	Developed as a PhD thesis under supervision from Mark Wardman.
Ownership and availability	The model is owned by Dr. Bill Lythgoe and would be available.
Software	Model has been developed in FORTRAN; the source code is available, but there is no user-friendly front end.
Applications to date	The model has been used to look into the demand of new parkway stations, and the impact of regular interval timetables on the East Coast Mainline.
Model structure	The model introduced by Lythgoe (2004) is an aggregate origin choice rail demand model estimated on data based on polygonal population zones around the origin station but with destination station dummies. The model is capable of forecasting rail passenger demand for new and adjusted services including those involving new origin or destination stations. The model has a cross-nested logit structure which allocated the share of total rail demand between competing origin station and allows the overall size of the rail market to expand or contract as rail fares and quality of service change. The cross-nested specification is developed to model differing degrees of dissimilarity between station choice pairs. This more generalised model form allows for differing degrees of competition between different origin stations. The logit specification also allows the application of population elasticities. The model is uni-modal

Basic approach to modelling	The model explains the trips between two stations in terms some or all of the following: • Fare and timetable related service quality of competing origin stations to the destination station. This includes measures of regularity, clockfaceness and memorability, using values from stated preference research • Population in zones around origin and destination stations • Access times and distances from origin population zones to origin and competitor origin stations. • Egress times and distances from destination and competitor destination stations to destination population zones. • Alternative car journeys The model is OD based; it can estimate the demand between any pair of stations, subject to availability of data.
Spatial coverage	The model covers the whole of the GB rail network
Zoning system	16 catchment area zones around each station
Time periods used	Annual
Time horizon	Medium to Long term
Inputs	Station catchment area data (population) , fares, GJT, car costs
Policy Variables	Fares and service level changes. The fares data will not allow ticket or TOC specific changes in fares.
Model Outputs	Absolute demand forecasts

PRAISE

Attribute	**Description**
Model name	PRAISE v3.2
Developed by	The *PRAISE* (Privatised Rail Services) model was developed at the Institute for Transport Studies, University of Leeds to (Whelan, 2002).
Ownership and availability	The model is owned by ITS
Software	The model is driven by a Windows based user interface and requires the prior installation of ACCESS. Permission would be required from the Strategic Rail Authority in order to access the supplied stopping pattern, fares, elasticities and demand databases.
Applications to date	It has been used look at the potential for open access competition following the privatisation of rail services (Whelan et al, 1997, Preston et al, 1999). The model was initially developed to assess competition on the Leeds to London corridor but it has subsequently been applied to other routes in the UK (Gatwick Express) and overseas (Stockholm to Gothenburg). A more recent version has been used to examine the value of scarcity on the East Coast Main Line (Johnson and Nash, 2004). It has also been used to examine the effect of ticketing policies on overcrowding (Whelan and Johnson, 2004).
Model structure	PRAISE comprises a disaggregate demand model, a cost model and an evaluation model.
Basic approach to modelling	The demand model has a hierarchical structure and works at the level of the individual traveller. Using information on passenger's valuation of journey attributes, together with elasticities, the lower level of the model assigns a probability that a traveller will choose a particular ticket and outward and return service combination. By aggregating these probabilities over a representative set of simulated passengers, the model forecasts market shares for each service and ticket combinations. The upper level of the model allows the rail market to expand or contract according to the overall level of service. By assessing the outward and return portions of a journey, together with information on ticketing restrictions (departure time, advanced purchase, transferability between operators), the model is able to forecast ticket revenue by operator. The demand model is calibrated to existing data on market shares and elasticities. The cost model employs a cost accounting approach incorporating, costs that are related to operating hours, train kilometres and fixed costs. Costs can be varied by operator and rolling stock type. The model generates output that can be used in a formal appraisal system, including user benefits, operating profits but not external costs.

Spatial coverage	Networks are built up by the user based on OD pairs, i.e. nodes rather than detailed networks. It is recommended to focus on smaller networks or simplifications of networks, as run times are otherwise prohibitive.
Zoning system	There is some aggregation of smaller stations implicit in the base demand data, but it is upto the user to merge data for stations if further aggregation is required.
Time periods used	Day
Time horizon	Short term
Inputs	Demand figures are actual demand figures supplied by the SRA and drawn by the user from a database of OD pairs. The user can also manually set demand figures as required. Costs require input from the user and can be expressed in terms of average per train km or per hour and are derived from sources such as the *Rail Industry Monitor*. Market shares for the model can be derived from CAPRI ticket sales data. Fares are specified by the user for each ticket/ OD pair, and can be derived from CAPRI data Journey opportunities for each OD pair are derived from a database of stopping patterns, supplied by SRA.
Policy Variables	Fares and service levels.
Model parameters/Elasticities	Generalised Journey Time Elasticities are supplied as a dataset to be used by the model. The values were taken from the industry standard Passenger Demand Forecasting Handbook. Values of time and adjustment time were also taken from PDFH, and are based on distance and journey purposes for each OD pair.
Model Outputs	Output includes, passenger demand, passenger distance, operator revenue, operator costs, profitability, user benefits (consumer surplus), overcrowding, and diversion to and from other modes in terms of passenger numbers and passenger distance.

National Rail Model

Attribute	**Description**
Model name	National Rail Model (NRM)
Developed by	The National Rail Model (NRM) was developed by FaberMaunsell on behalf of the Department for Transport as part of the Department's multi-modal modelling capability.
Ownership and availability	The model is now owned by the Department for Transport
Software	Part of the NTM and EMME/2
Applications to date	The National Rail Model has been developed as part of the Department's multi-modal modelling package to test the Governments TEN Year Plan strategies.
Model structure	The NRM is a strategic model

Basic approach to modelling	The model works in an iterative way moving through a number of key sub-models, the most important being a mode choice model and a trip assignment model. The mode choice model generates a multi-modal trip matrix based on modal costs and this matrix is then passed to the EMME/2 assignment package that loads passengers to the network of services. This assignment is based on the concept of optimal strategies whereby passengers chooses a set of paths through the network and board the first train to arrive at their destination. There is no individual based choice mechanism - the algorithm identifies a set of attractive alternatives and then distributes the demand amongst the attractive routes. • The model has network and service representations for both AM peak and inter-peak periods, services being coded to the entire British 99/00 timetable. • The base year is 1998, using National Rail Passenger Model and London Underground trip data. Rail demand and network models were calibrated against observed rail demands by conurbation and main corridor. • For future runs, trips from Pass1 are disaggregated to DRDM zone level, using population and generalised cost elasticities. • Passenger growth is linked to the predicted changes in rail demand output from the Pass1 model. • A public transport assignment process including a crowding time element to reflect overcrowding. • Rail Policy User interfaces to specify various scenarios • The model must also produces outputs which can be input to the TUBA cost-benefit analysis program. The detailed rail network model is consistent with the PLANET model.
Spatial coverage	The model covers all national rail and London Underground stations.
Zoning system	Zones were direct aggregations of wards, with Greater London area and other conurbations disaggregated in greater detail. Zones may also be split where they cover competing rail corridors. The model has 1318 zones, each of which can be broken down into 1 of 17 Pass1 area types.
Time periods used	Annual
Time horizon	Medium to long term

Inputs	The demands come from the 1997 National Rail Passenger Matrix (derived from Computer Analysis of Passenger Revenue Information (CAPRI) ticket sales data), uprated to 1998 levels. This contains the annual number of tickets sold between about 2500 rail stations in Great Britain. London Underground trips for 1998, originally derived from the London Area Transport Survey (LATS), are added to these, and the whole set of station-to-station demands are then mapped to the geographical zones. Lastly, the time profile for rail trips from the National Trip-end Model (NTEM) is applied, to give a full picture of base year GB rail movements. Base year national rail fares between zones are estimated using an econometric model of a sample of actual rail fares, on the basis of distance and ticket type. London Underground fares are simpler, and so base year Underground fares are derived from the actual prices for trips between different zone combinations. The NRM contains a full, geographical representation of current and planned national rail, London Underground, and Docklands Light Rail stations and networks, and all the services operated on them, according to the 1999 summer timetable. The service data includes the capacity of each service, and the type of rolling stock from which it is formed, to inform calculations of overcrowding and emissions. Transit lines include nearly all services in the summer 1999/2000 timetable, modelled in the morning and inter peak periods. Rail investment policies can be represented either as generic changes in service frequency, capacity or speed, or as packages of changes to individual services, representing particular enhancement schemes. Changes to fares can also be represented at the level of broad route corridors.
Model parameters/Elasticities	Values of time are taken from the Transport Economics Note (DfT, 2000). The calibration process produced a set of sensitivity parameters and calibration constants, chosen to reproduce as far as possible: rail trip with respect to ticket price demand elasticity of -0.5. The elasticities associated with long distance travel are markedly higher than those associated with shorter distance rail travel in London and the South-East. This effect can be attributed to higher degree of competition between car and rail for longer distance travel. NTM elasticities are broadly of the same magnitude as PDFH values, and that there is a similar relationship between the elasticities of different market segments. The growth in rail trips from the base year in the National Rail Model is based on established industry-standard income elasticities and time trends for the low end of the range, and extra econometric evidence for the high end.

Model Outputs	Model outputs include passenger kms, passenger hours, PIXC indicators and -emissions categorised by corridor/ area type.

PLANET Suite

Attribute	**Description**
Model name	Planet Suite or PS2002
Developed by	The model was originally commissioned by British Rail based on the 1991 National Rail Timetable but has subsequently been developed by Jacobs and Atkins on behalf of the Strategic Rail Authority.
Ownership and availability	SRA
Software	The model requires the PLANET software package and the EMME/2 software environment to allow extensive user interaction to the computer environment, regarding inputs and outputs in particular.
Applications to date	The PLANET Suite has been used by the SRA to evaluate many projects including: • Thameslink 2000 • CrossRail Business Case • Strategic Plan 2003 • European Rail Traffic Management System (ERTMS) • Great Western Route modernisation • East-West Midlands Multi-Modal Study
Model structure	The PS2002 Suite is a set of network assignment models consisting of morning and interpeak South and North models used for the forecasting and appraisal of rail schemes in the UK It has a current forecasting mode for base demand and a forecast mode for estimating changes in travel demand arising through the switching between rail services, changes in mode split and trip distribution. Outputs are then used to populate an appraisal template. Planet Strategic also contains an incremental mode choice model.

Basic approach to modelling	The model assigns a base demand matrix to the network. The EMME/2 network assignment package loads a passenger demand matrix to a network of rail services in an iterative way taking account of capacity and crowding constraints. The assignment procedure in EMME/2 is based on the concept of a "strategy": for any particular journey a set of "attractive lines" is calculated, and a passenger then boards the first vehicle to arrive from any of these lines. Base generalised journey time matrices are then estimated which are passed to a elasticity model to estimate the demand impact of changes to the network. The revised demand matrix is then passed back to the assignment model to be loaded onto the network to generate passenger and train based outputs. These are presented by mode, operator and by rail/underground service groupings. There are four demand matrices included in the assignment procedure, Business, Commuter, Leisure and Total demand. Each demand matrix is assigned separately to calculate journey specific crowding factors. These are combined and weighted to calculate overall crowding factor in the scenario. Crowding takes account of the multiple journey purposes, so there are separate demand and supply profiles for each journey purpose and service categories, with separate profiles for Underground demand and supply. PS2002 can be run in different ways, from a simple crowded assignment model to a complete run where the elasticity sub-model interacts with the supply side to calculate demand response to a change in the network.
Spatial coverage	The Planet models cover the GB rail network.
Zoning system	Planet Strategic has 250 Zones, Planet North has 1600, with a finer disaggregation in the North, and Planet South has 1400 zones with a finer disaggregation in the South, particularly the South East. Planet Strategic has 250 Zones with a more uniform coverage of detail over entire GB rail network
Time periods used	Planet Strategic is an all day model, South and North cover the morning peak 0700-0959 and inter-peak (1000-1559) periods separately
Time horizon	Planet can forecast annually for any specified time horizon.

Inputs	Train Service Database. Planet uses this to create 'transit lines' containing information on TOC, CAPRI service group, key station and direction for each node passed through. Computer Analysis of Passenger Revenue Information (CAPRI) for station to station ticket sales. Operational Research Computer Allocation of Tickets to Services (ORCATS) used to factor daily demand to AM / IP periods
Policy Variables	Fare factors are used for each TOC/ journey purpose/ ticket type combination in terms of pence per mile. Because of the absence of a behavioural model and more specific elasticities, changes in fares cannot be modelled in much detail.
Model parameters/Elasticities	The elasticity sub model requires GDP and fare elasticities are used for each journey purpose. In the appraisal template, values of time for different journey purposes are based on PDFH and Transport Economics Note (TEN) values
Model Outputs	Outputs include estimates of passenger kilometres, total passenger hours, un-crowded passenger hours, crowded passenger hours, passenger boardings and train kilometres, generalised journey time components. An elasticity sub model is used to determine the impact on demand levels of a change in the modelled network, such as a new service or changes in service frequency, based on GDP and fare elasticities by journey purpose. Zonal outputs from PLANET are generated at three levels: local area, sub-region and region. The path between any two individual nodes can be analysed using the disaggregate analysis of trips. The SRA require a full economic appraisal to be carried out on all schemes tested. The outputs and cost inputs are converted into value for money measures which can be changed transparently by manipulating growth and other assumptions. The economic benefits from highway impacts can be taken into account based on outputs from the SATURN highway model.

APPENDIX 2: FREIGHT MODEL INVENTORY

Great Britain Freight Model (GBFM)

Attribute	**Description**
Model Name	Great Britain Freight Model(GBFM)
Developed by	MDS Transmodal in the early 1990s, originally for a study of cross-Channel ferry traffic. Subsequently expanded with some ITS input as part of the EU STEMM project.
Applications to date	A number of projects subsequent to STEMM, including the Merseyside Freight Study and the SRA Freight Strategy work. The model has been enhanced incrementally and in a somewhat ad-hoc manner in order to undertake these projects. The GB domestic module, for example, is a relatively recent addition
Spatial coverage	GB, with a coarser network of European zones and a fairly basic representation of other GB trading partners
Zoning system	2700 zones in GB, based on postcode boundaries. The overseas zone structure is much coarser
Time periods used	Years
Time horizon	Forecasts to 2010 as part of the SRA study. Can be used to forecast up to 2030
Modes covered	Road, rail, basic representation of water and coastal
Sources of freight data	CSRGT Network Rail rail freight data UK Customs and Excise Trade Statistics
Network systems used	Relatively finely defined GB road network, the same as used in the National Transport Model Rail origins and destinations are fully coded but the network is ‘virtual’ at present
Can it handle intermodal?	Yes. Road, bulk rail and unitised freight are subject to separate cost estimations
Nature of cost relationships, by mode	Builds ‘accounting’ models of cost for each mode, as an approximation to freight rates. Generalised cost is estimated through addition of time-based costs and reliability-based costs
Basic approach to modelling	Mode split is based on the ITS F-Logit formulation
Are trip origins and destinations related to economic activity?	No. The model uses base year zone origin and destination estimates in order to produce a trip distribution matrix, consistent with data on average lengths of haul in each commodity. This matrix is then used as the basis for trend projection.

Is there any attempt to represent logistics structures?	Very limited. Average trip lengths change over time for each commodity group (where such trends are apparent) as a reflection of supply chain trends. This entails adjusting the O-D matrices to increase the proportion of freight on longer O-D pairs. There is also an ability to build trans-shipment points (with local storage) to model logistics 'chaining' effects
Commodity detail / coding system	NST system. Currently uses 17 commodity codes, plus 'intermodal', 'own haul' and 'Channel Tunnel'. It is not clear how much of the data input (e.g. assumed values of time, values of reliability) are commodity group specific
Is it part of a general transport model, including passenger travel?	The model is a stand-alone freight model but is used as the freight module for the DfT's National Transport Model suite.
Suitable for trend projection?	Yes, this facility is built in to the model
Suitable for policy testing?	Yes – the scenarios are designed by the user
Ownership and availability for use?	Owned by MDS Transmodal and available for use by ITS for research purposes only. Can be made available to others for an appropriate fee. Evident concern regarding the model's availability for use, and the need to ascertain its potential as part of a more comprehensive National Transport Model, led DfT to commission production of better documentation and carry out an audit in 2003.

EUNET Model (TransPennine Model)

Model Name	**EUNET Model (TransPennine Model)**
Developed by	ME & P
Applications to date	The EUNET project team applied the model to the TransPennine corridor, as a demonstration project. It has subsequently been used on a number of studies involving TransPennine traffic (e.g. relevant multimodal transport studies)
Spatial coverage	UK and external zones – but spatial detail declines rapidly away from the immediate TransPennine corridor
Zoning system	92 zones in the UK – of which 60 are in the TransPennine area
Time periods used	Annual
Time horizon	25 years. Forecasts to 2020 in the original version (1995-2020)
Modes covered	Road, rail, air, maritime – but forecasting on the TP route is limited to rail and 2 categories of road vehicle
Sources of freight data	CSRGT Rail freight matrices estimated by the study team
Network systems used	Relatively detailed networks (various types of links are specified, 28,000 links altogether)
Can it handle intermodal?	Intermodal facilities are represented in the network specification
Nature of cost relationships, by mode	Generalised cost – on the basis of monetary costs and a value of time
Basic approach to modelling	Hierarchical logit formulation to divide between rail and road, then between HGV1 and HGV2
Are trip origins and destinations related to economic activity?	Yes. The model uses input-output tables to relate trip ends to economic activity (GDP and employment).
Is there any attempt to represent logistics structures?	Yes. The model can handle loading/unloading, warehousing and local distribution as well as trunk transport for each commodity
Commodity detail / coding system	9 commodity types used, roughly equivalent to NST/R
Is it part of a general transport model, including passenger travel?	Yes
Suitable for trend projection?	Yes. There are various trends built in, e.g. a trend towards growing international trade. GDP and employment forecasts can be used to forecast freight trends

Suitable for policy testing?	Yes, the original test examined the likely impact of motorway tolling on the central stretch of the M62
Ownership and availability for use?	ME & P (now part of WSP)

SKM 'Additional Freight Model'

Model Name	**SKM 'Additional Freight Model'**
Developed by	Sinclair Knight Merz, AEA Technology Rail and ITS Leeds, to inform development of the SRA Freight Strategy
Applications to date	SRA Freight Strategy
Spatial coverage	GB
Zoning system	Originally had no geographical dimension, but apparently worked at county level for the SRA study
Time periods used	Annual
Time horizon	Forecasts for road+rail tonnes and tonne-kilometres by product group, up to 2020
Modes covered	Road and rail
Sources of freight data	CSRGT EWS and Freightliner rail freight data provided via SRA
Network systems used	No
Can it handle intermodal?	No
Nature of cost relationships, by mode	Road transport costs, by size of road vehicle. Generalised costs estimated for each mode. The model estimates breakeven distances, by product group.
Basic approach to modelling	Freight demand and mode choice model. The total amount of freight is related to GDP. Some freight is deemed captive to certain modes. Mode shares for other freight are estimated through a binary logit model using relative generalised costs for each mode.
Are trip origins and destinations related to economic activity?	Whilst the total amount of freight is related to GDP, there would not appear to be any regional or more local variation in the GDP values used.
Is there any attempt to represent logistics structures?	No
Commodity detail / coding system	Seven product groups, plus 'miscellaneous', 'intermodal containerised' and 'intermodal unitised' were modelled for the SRA Freight Strategy study.

Is it part of a general transport model, including passenger travel?	No
Suitable for trend projection?	Yes, the model regresses the transport data against GDP projections for the forecast period.
Suitable for policy testing?	Yes. A range of scenarios affecting road and rail costs were tested for the SRA.
Ownership and availability for use?	SRA claims ownership. The model has been used on Multimodal transport studies (and also a study for the CfIT) where SKM was a consortium member.

SRA Freight Interchange (CAST-DPM) Model

Model Name	**SRA Freight Interchange (CAST-DPM) Model**
Developed by	Radical (owners of CAST-DPM location software) and Exel
Applications to date	Strategy study of rail freight interchange locations
Spatial coverage	GB
Zoning system	The data would seem to be coded with great spatial accuracy, according to OS grid references, rather than allocated to zones.
Time periods used	Model estimated at a particular point in time using freight data for that period
Time horizon	See above
Modes covered	Road and rail
Sources of freight data	CSRGT SRA rail freight data
Network systems used	CAST-DPM has a high detail of road network. Railtrack GIS-coded rail network Database of c.2,000 actual and potential rail interchange locations
Can it handle intermodal?	Not explicitly – presumably it is accepted that some of the freight captured by terminals would be intermodal rather than multimodal.
Nature of cost relationships, by mode	Transport costs (trunk, interchange, collection and delivery) plus inventory costs?
Basic approach to modelling	Deterministic – minimum cost approach
Are trip origins and destinations related to economic activity?	Yes. Production of each commodity is related to industrial production and consumption is related to population demographics
Is there any attempt to represent logistics structures?	Yes – supply chains have been mapped for the product groups selected
Commodity detail / coding system	Only tested for a limited range of product groups felt to be relevant to the rail freight interchange scenario

Is it part of a general transport model, including passenger travel?	No
Suitable for trend projection?	Not as operated for the study in question. Presumably future traffic projections could be input to re-run optimal terminal locations for future time periods.
Suitable for policy testing?	Yes. Modal shift can be examined with respect to changes in costs of each mode
Ownership and availability for use?	SRA. Access to data is strictly controlled. Discretionary access to model and data has been provided for consortia undertaking multi-modal transport studies (MMS).

Leeds Freight Model (LEFT model)

Model Name	**Leeds Freight Model (LEFT model)**
Developed by	ITS University of Leeds as part of its contribution to the ITeLS project
Applications to date	High-level testing of various transport policy options and their effects on road/rail market shares in GB
Spatial coverage	GB
Zoning system	No
Time periods used	Input data is annual
Time horizon	Currently being used for testing up to year 2010 on low, medium and high GDP projections
Modes covered	Road and rail
Sources of freight data	CSRGT Rail freight data obtained via SRA
Network systems used	No
Can it handle intermodal?	No
Nature of cost relationships, by mode	Linear cost relationships for road, bulk rail and unitised rail. Monetary transport costs cover trunk transport movements for road and bulk rail, plus interchange and collection & delivery costs for unitised rail. Generalised cost comprises monetary costs plus time-based costs and reliability-based costs.
Basic approach to modelling	Modal shares are estimated using a binary logit formulation
Are trip origins and destinations related to economic activity?	No
Is there any attempt to represent logistics structures?	No
Commodity detail / coding system	6 broad commodity groups plus ‘general/other’, broadly in line with NST headings
Is it part of a general transport model, including passenger travel?	No

Suitable for trend projection?	Yes. The model is designed for broad-brush testing of the effects of policy options (currently up to 2010) against the background of low, medium and high GDP projections
Suitable for policy testing?	Yes. The model is designed for high-level strategic analysis. Relatively low levels of commodity disaggregation and the lack of any spatial/zonal detail allow for rapid testing of strategic options.
Ownership and availability for use?	ITS. The model is still under development.

APPENDIX 3: PASSENGER MODEL DEVELOPMENT

1 Introduction

This appendix sets out a structure for a new inter-urban aggregate rail demand model. The model draws heavily on existing industry methodology and evidence (as set out in the PDFH) and the focus is this work is on model application rather than wholesale model development.

2 Model Structure

The general form for the demand model sets the volume (V) of demand between stations i and j as a function of the fare between the two stations (F_{ij}), the level of generalised journey time between the two stations (GJT_{ij}), the degree of cross modal competition (M_{ij}) the generating potential of the origin station (O_i) and attracting potential of the destination station (D_j).

$$V_{ij} = h\left(F_{ij}, GJT_{ij}, M_{ij}, O_i, D_j\right) \qquad (1)$$

Details of the specification of each variable are presented below.

(a) Rail Fares

From a policy testing perspective it is important that the model is capable of assessing changes to fares and interactions between different ticket types. This will help facilitate policy testing relating to capacity utilisation and crowding, as well as revenue growth.

The Passenger Demand Forecasting Handbook (PDFH) sets out a constant elasticity based methodology for forecasting the change in volume due to changes in fare and fare related factors. This approach is centred on application based up average fare changes but can be adapted to assess interactions between products using cross-ticket elasticities. The Handbook summarises a wealth of information of fare elasticities and it is intended to draw on this information during the development of the new demand model. There are, however, three issues which will require further attention.

- Economic theory suggests that the price elasticity of demand should increase as the price of a good increase therefore is a constant elasticity model appropriate when considering large fare changes over a long time horizon?
- Much of the PDFH elasticity evidence relates to short run effects. There is however an increasing interest in long run impacts and an emerging literature. The cross-sectional data used for model calibration is not suitable for dynamic analysis but it may be possible to incorporate external evidence within the application methodology.
- There are complex interactions between ticket types which are arguably more suited to disaggregate analysis such as that employed by PRAISE. It will therefore be useful to draw on evidence from this model when considering pricing strategies.

(b) Rail Service Quality

The level of rail service quality can be measured in terms of the generalised journey time (GJT). This composite variable is taken as a function of the in-vehicle time (IVT), a service frequency penalty (FP) and an interchange penalty (IP). Details of the formulation of each GJT element can be found in the PDFH.

$$GJT = IVT + FP + IP \tag{2}$$

The GJT metric presents the standard way to measure average service quality for a given timetable on a given flow. Changes in the volume of rail demand following changes to the overall level of rail service can be expressed via the GJT elasticity and where necessary it is intended that GJT elasticity estimates by drawn from PDFH.

The measure of generalised journey time relates only to timetable related service quality (journey time, headway and interchange) and does not include other service quality issues such as rolling stock quality, reliability and crowding. Due to lack of appropriate data we do not intend to incorporate these impacts within the model.

(c) Cross Modal Competition

In the interurban context the principal competitors to rail are car, coach and air and the attractiveness of these modes can influence both the demand for rail and rail's own elasticity of demand. Where customers have good alternatives to rail they are likely to exhibit higher elasticities of demand and this issue is incorporated within PDFH evidence.

If however we wish to look at how a change in the competitive position of alternatives modes to rail then we can use cross-elasticities of demand. Given that it is very unlikely that the project will have access to flow based time and costs data for alternative modes it is likely that any cross modal impacts will be introduced using an incremental cross elasticity approach which shift the rail demand curve in response to changes in competition. The Handbook currently contains cross-elasticity evidence on car fuel cost, car journey time, bus cost, bus time, bus headway, air cost and air headway.

(d) External Influences

The range of external factors that influence the demand for rail trips include changes to population, car ownership, employment, and income.

At an aggregate level we can assess the influence of changes to external factors using a simple elasticity approach, however, the influence of external factors on rail demand will depend, at least in part, on the accessibility of stations and their catchment areas. This introduces an additional modelling dimension to represent origin and destination specific effects.

A straightforward model which serves as a reference point for other models, as well as allowing an assessment of the parameter estimates and implicitly the quality of the data, involves the specification of origin and destination station specific dummy variables. These models take account of the generating and attracting potential of each station and allow for an unbiased estimation of the sensitivity of demand to changes in fare, GJT and cross modal competition. Such a model, in constant elasticity form, is represented as:

$$V_{ij} = \mu F_{ij}^{f} GJT_{ij}^{g} M_{ij}^{m} \exp\left(\sum_{i=1}^{r-1} \gamma_i O_i \sum_{j=1}^{s-1} \delta_j D_j\right) \qquad (3)$$

If there are r origin stations and s destination stations, r-1 origin specific dummies and s-1 destination specific dummies can be specified and their respective coefficients are interpreted relative to the arbitrarily omitted categories.

Although the dummy variable approach can capture the existing origin and destination generation and attraction impacts it is not capable of assessing the demand impacts of changes to external factors. This requires a different approach which involves the replacement of the origin and destination specific dummy variables by catchment area specifications that weight the population in zones surrounding each station, as illustrated in Figure 1, as a function of their distance from the station. Changes to the socio-demographics in zones located further away from the station should be given less weight than those located near to the station.

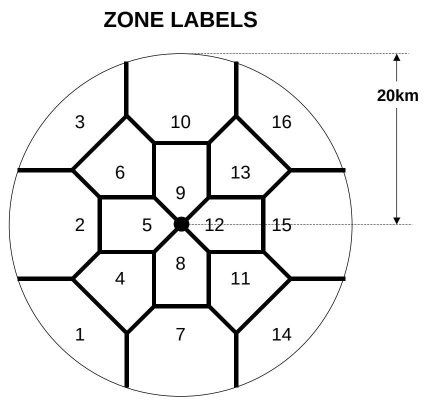

Figure 1: Illustrative Station Catchment Area Zoning System

Following the constant elasticity approach adopted in the PDFH we can specify the demand originating in zone a around station i and travelling to destination zone b around station j as a function of the population in origin zone a (P_a), the population in destination zone b (P_b), the access time from zone a to the origin station (A_a) and the egress time from the destination station to egress zone b (E_b), the fare and generalised journey time involved in travelling between stations i and j and the degree of cross-modal competition:

$$V_{aijb} = \mu F_{ij}^{f} GJT_{ij}^{g} M_{ij}^{m} A_a^{\alpha_1} P_a^{u} E_b^{\alpha_2} P_b^{v} \qquad (4)$$

The main problem with equation 4 is that we do not know, from ticket sales data, the precise origins and destinations of travellers. All we know is the number travelling between stations i and j. However, we do know that the volume of demand between i and j is made up of the sum of all the journeys from the various origins to the various destinations:

$$V_{ij} = \sum_{a} \sum_{b} V_{aijb} \quad (5)$$

Hence by substituting V_{aijb} of equation 4 into equation 5 we can express observed demand in terms of observed independent variables. Thus the parameters of equation 4 can be estimated, using non-linear least squares, even though we cannot observe the precise origins and destinations of rail travellers.

As this is a relatively underdeveloped area of research we aim to devote a significant effort to examining functional form issues as well as the selection of a range of socio-demographic influences on rail demand.

3 Model Estimation

A considerable effort will be required to define the base network and assemble the explanatory variables relating to each flow and each station catchment area. The required data for each flow for the base period includes:

- Demand – point to point demand and revenue data drawn from the 1999/2000 CAPRI ticket sales database;
- Fares by ticket type – average revenues for full, reduced and season tickets;
- Rail service quality will be measured via generalised journey time – including estimates of in-vehicle time, service frequency and interchange requirement drawn from MOIRA (see section 3.2.2);
- To facilitate forecasts for demographic changes, station catchment areas will be defined using 2001 Census data on population, car ownership and employment together with estimates of average household income by postcode sector supplied by Experian.

Once the data is assembled, cross-sectional regression models will be calibrated to the data to derive robust parameter estimates. It is envisaged that separate parameters will be estimated for a range of flows longer than 20miles, including:

- To London Seasons
- To London Non-Seasons
- From London Seasons
- From London Non-Seasons
- Non-London Seasons
- Non-London Non-Seasons

In most instances coefficients to fares, service quality and cross-modal competition will be constrained to equal those in the PDFH with attention given to estimating new catchment area functions.

An important part of the calibration process will be a full audit of estimated parameters to ensure they are in line with other evidence and a validation of the model using “back-casting” procedures on key flows.

4 Model Application and Outputs

Following model estimation a representative sample of flows will be entered into a spreadsheet based application tool that will allow the user to examine a range of policy tests. The principal outputs of this application tool will include a matrix of journeys, passenger kilometres and revenues by flow, disaggregated by ticket type. The output for the sample of flows will be expanded to generate forecasts for the network as a whole.

The strategic nature of the policy tests will necessitate a long forecasting time horizon with model outputs being generated across 30 years. These outputs will then be used as inputs to a more formal economic appraisal framework such as those used in the Department for Transport’s recent Multi-Modal Studies. The appraisal system will not however deal with changes to operating and capital costs, which will need to be estimated separately.