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Rail Passenger Demand Forecasting Methodology
TAG Unit 3.15.4

April 2009

Department for Transport

Transport Analysis Guidance (TAG)

This Unit is part of a family which can be accessed at www.webtag.org.uk

Contents

1. Summary

1.1.1. The purpose of this unit is to describe the approach to demand forecasting required by the Department for Transport (DfT) for estimating future rail patronage. This approach is very similar to that used elsewhere within the rail industry but with a small number of amendments to reflect the strategic and longer term forecasting needs of DfT.

1.1.2. The methodology should be applied to all DfT Rail and National Networks (RNN) Group demand forecasting applications, including:

- Strategic planning - including application of the Network Modelling Framework (NMF)
- Regional forecasts - including Regional Planning Assessments (RPAs)
- Franchise analysis - specification, bid assessment, ad-hoc initiatives
- Financial forecasts - forecasting Train Operating Company (TOC) revenue
- Scheme appraisal - of both programmes and projects

1.1.3. Users of this guidance should bear in mind the ongoing programme of work to improve rail passenger demand forecasting methods. The Department for Transport is funding major primary research to improve our treatment of background growth and fares. At the same time the Passenger Demand Forecasting Council (PDFC) is planning to produce a revised version of the Passenger Demand Forecasting Handbook during 2009. This will incorporate a significant quantity of new research that has been completed since the last edition was released in June 2005. The recommendations within this Transport Appraisal Guidance Unit will be revisited in light of these developments.

2. Introduction

2.1.1. The focus of this methodology is on producing revenue and patronage forecasts (passenger journeys and passenger kilometres) for the GB rail network. For multi-modal modelling and demand forecasts of competing modes (car, air, bus and Underground), DfT's Technical and Professional (T&P) directorate and Integrated Transport Economics and Appraisal (ITEA) division should be consulted. On occasions sponsors may wish to apply a bespoke forecasting approach. Where this is proposed the suggested methodology must be agreed with representatives of DfT's Rail Technical and Professional (T&P) directorate. To enable comparison, the resultant forecasts must be reported alongside forecasts produced using the methodology described below.

2.1.2. No forecasting exercise can hope to reflect every single influence upon passenger demand in complete accuracy. It is more realistic to require that the forecasting approach should reflect adequately the main features and interactions identified in the transport market being examined, and to understand the level of uncertainty in the outputs of the demand forecasting exercise.

2.1.3. To some extent there is a trade-off between accuracy and the cost, time-scale and complexity of a demand forecasting exercise. Therefore an appropriate level of proportionality must be maintained. In some cases considerable insights can be achieved within a relatively short space of time and cost. However, in other cases the additional time devoted to developing a forecasting tool or refining an existing model may be invaluable in understanding complex travel market interactions. The selection of a forecasting approach should be an iterative process which balances issues of functionality, model specification, data availability, accuracy, complexity and resource and time constraints.

2.1.4. This unit proceeds as follows. Section 3 outlines the two principal approaches to modelling rail passenger demand and section 4 describes the approach used in the Passenger Demand Forecasting Handbook (PDFH). Section 5 then explains how this approach should be amended to reflect the strategic and longer term forecasting needs of DfT. Section 6 proposes a small number of sensitivity tests to test new forecasting approaches and section 7 concludes by describing DfT forecasting requirements.

3. Forecasting Approach

3.1.1. There are two principal approaches to modelling rail passenger demand. Firstly, models have been developed explicitly to estimate the overall demand for travel and to consider the impact of potential interventions across the transport system as a whole. These models represent travel decisions as a series of linked choices (whether to make a trip, where to travel to, when to travel, the mode and the route) and have historically been developed as part of transport studies which consider all transport modes together. They have the advantage of providing a comprehensive picture of transport demand so that, for example, the impact of a new rail service on road traffic and on the number of trips to key destinations may be readily forecast. Web-TAG Unit 3.10 (www.webtag.org.uk) provides more information on developing variable demand models of this type.

3.1.2. Unfortunately, there are a number of disadvantages to these models when forecasting the demand for rail travel which mean they are not used more widely for planning our railways. Existing multi-modal models treat the link between rail demand and income very differently from elasticity-based models. This discrepancy manifests itself for some journey purposes as an observed divergence between forecasts of rail demand generated by the different approaches. Other challenges to forecasting the demand for rail within a multi-modal framework include:

- **Data** – To obtain an accurate calibration, multimodal models require a comprehensive trip origin-destination matrix which describes the ultimate origin and destination of journeys made by all modes. The costs of obtaining a sufficiently large sample of rail users/trips from household survey data are prohibitively large.

- **Accuracy** - multi-modal models are least accurate when estimating demand on minority modes e.g. rail constitutes around two percent of all journeys within Great Britain.

- **Cost** - The data and processing requirements of multi-modal models mean they are generally more expensive to build, maintain and run.

3.1.3. As a consequence of the challenges described above, rail forecasts are more commonly prepared using an incremental "elasticity" based method or model. In this approach we seek to determine a statistical relationship between the observed demand for travel (in this case rail services) and variables representing those factors (income, employment, service quality, fare etc.) that affect the demand for travel on a mode-by-mode basis. For example if improvements to rolling stock result in a more comfortable journey, the number of trips generated will be estimated by reference to the volume using the unimproved service and the change in service quality delivered by the new rolling stock. This is the standard approach employed across most of the UK rail industry (for a rail intervention in London the RailPlan software tool is used to model the interaction between different public transport modes) and has the particular benefit that it does not require data and parameters for those attributes that remain constant.

4. The Passenger Demand Forecasting Handbook Framework

4.1.1. Forecasting parameters are drawn from previous experience and research. The principal source for rail passengers is the Passenger Demand Forecasting Handbook (PDFH). This provides the best estimates of demand effects that can be made at the moment and provides guidance on applying this knowledge to the preparation of passenger demand forecasts. A significantly revised version of the PDFH was released in 2002 (v4) and was further updated in 2005 (v4.1). The forecasting parameters set out in these two versions form the basis of the forecasting methodology described in this document.

4.1.2. The elasticity-based forecasting approach is usually simplified into two main categories. Firstly, background (exogenous) changes to rail demand that are caused by factors assumed to be outside the direct control of the rail industry. These include factors such as employment and population changes, GDP growth and changes to other modes (such as increased congestion or new highway schemes). The current PDFH approach covers 11 exogenous growth factors/drivers as described below. These factors are also included in the RIFF-Lite forecasting tool which has been developed to implement PDFH recommendations and assist in producing exogenous demand forecasts.

- GDP or employment
- Population
- Car Ownership
- Car Fuel Costs
- Car Journey Time
- Bus Cost
- Bus Journey Time
- Bus Headway
- Air Cost
- Air Headway
- Underground Cost

4.1.3. Secondly, scheme or policy-related (endogenous) initiatives which are assumed to be within the direct control of the rail industry and Government. These include changes to rail services, reliability and performance, new stations, terminal or lines, and changes in rail fares levels or freight grants. The endogenous variables included in the current PDFH approach are:

- Fares
- Generalised Journey Time (GJT) incorporating in-vehicle time, frequency and interchange
- Performance
- Non-timetable related service quality (focusing mainly on crowding, station facilities and new/refurbished rolling stock)

4.1.4. A basic forecasting requirement for all applications is a base demand forecast called the 'without-intervention' case. This is driven largely by exogenous factors outside the control of DfT Rail and TOCs, but should also include any committed initiatives (endogenous drivers) which are due to be implemented during the forecast period. When carrying out appraisal forecasts are also required for option testing or 'with-intervention' scenarios (see Web-TAG Uncertainty Unit 3.15.5 for more details). These should retain the same exogenous growth characteristics of the 'without-intervention' scenario, but also include any changes in endogenous factors specific to the intervention under scrutiny. Examples include infrastructure enhancements, alternative franchise specifications, fares changes, rolling stock improvements and options for strategic planning.

5. Using the DfT Forecasting Methodology

5.1. Implementing the PDFH Approach

5.1.1. In practice, two core forecasts are required.

- the central forecast using the PDFH 4.1 recommended parameters and approach
- an alternative forecast using the DfT amended approach detailed below

5.1.2. The application of PDFH requires detailed information on the base flows. At present we typically use LENNON ticket sales data as a proxy for rail demand. Additional information on the demand for rail travel can be obtained from TOC management accounts, passenger surveys, passenger counts and MOIRA. At present there are some gaps in the station to station matrix for UK rail trips. In particular there are significant gaps in our knowledge of travel within urban areas due to the large proportion of journeys which are carried out on travelcard products. We also have limited ultimate origin-destination data for rail journeys, although this can be improved with survey data, including the National Rail Travel Survey (NRTS).

5.1.3. The core forecasts should both use the data sources as recommended in Web-TAG unless there is sufficient good-quality evidence to suggest otherwise. Any divergence from Web-TAG must be discussed with DfT Technical and Professional prior to implementation. Forecasting parameters should be taken from PDFH 4 and 4.1 as set out in Table 1 below.

	PDFH version	PDFH chapter	PDFH tables	Notes
GDP, Employment, Population, Car Ownership, Car Fuel Costs, Car Journey Time, Bus Cost, Bus Journey Time, Bus Headway, Air Cost, Air Headway, Underground Cost	4.1	B1	B1.1 to B1.7	
Fares	4.0/4.1	B2		See specific methodology below
GJT	4.1	B3	B3.1 to B3.11	
Performance	4.1	B4		
Crowding	4.1	B5	B5.1	See specific methodology below

Station Facilities	4.1	B5		See specific methodology below
Rolling Stock	4.1	B5		

Table 1: DfT Rail Forecasts - PDFH Parameters

5.1.4. PDFH exogenous background elasticities have been calibrated on regional data for the period 1990-1998 i.e. financial years 1990/91 to 1998/99. However PDFH is applied at a more detailed level and so trips within regions can be forecast using base demand to/from sub-regional centres with respect to the drivers/elasticities. For example, forecasting trips within West Yorkshire between Leeds and Bradford would use the forecasting parameters in Table B1.5 in PDFH 4.1 (non-London short-distance flows) and source the growth rates for the relevant drivers from TEMPRO (see www.tempro.org.uk and Web-TAG Unit 3.15.2 for further information). Additional guidance regarding the use of TEMPRO for elasticity-based forecasting can be found later in this unit.

5.2. Amending the PDFH Approach

5.2.1. A small number of changes to the PDFH approach are needed to provide the DfT-amended forecasts. These amendments are derived from concerns with the application of PDFH to the strategic and longer term forecasting needs of DfT. It should be noted that the amendments to the PDFH approach described here are interim recommendations since further research is required to better understand the issues raised. In addition to implementing this interim guidance, DfT intend to pursue a programme of rigorous primary research to improve the elasticity-based approach. This programme is informed by key policy milestones and has been developed in close collaboration with other government representatives and the rail industry.

5.2.2. There are three key areas that require an alternative approach. The specific amendments are described below.

- **Station Facilities** - Most station proposals cover minor maintenance backlog, CCTV provision, shelters, toilets, security etc. PDFH suggests that demand increases of between 5% and 10% can be generated from investment to improve station facilities. However, since station improvements will normally exhibit diminishing returns to investment expenditure and passenger expectations of station facilities will adjust upwards as incremental improvements to facilities are made, total long-term values for demand uplifts above 2% are unlikely and would need detailed justification

- **Fares** - The elasticity recommendations in Chapter B of PDFH version 4 (rather than version 4.1) should be applied to high level assumptions regarding changes to fares. This means an overall change which is applied across all ticket types i.e. RPI + 1% for regulated fares. For anything more complex and detailed than an overall fares change a bespoke fares model should be considered.

  The 2007 Rail White Paper *Delivering a Sustainable Railway* describes how the Government intends to simplify the existing fares structure to make the railway easier to use and to improve the confidence of passengers in the system. In addition, the supporting document *Saver Fares: Differentiation and Potential Deregulation* describes how differentiated fares should be modelled. If further information is required DfT Technical and Professional can provide advice in these circumstances.

- **Crowding** - The approach to crowding specified in PDFH can be summarised as follows. Passengers who experience crowding (whether seated or required to stand) attach a penalty to the busy conditions in which they must travel. This penalty reflects the dis-benefit associated with physical discomfort, a reduced ability to work or read etc. and is expressed in monetary terms. These crowding penalties are subsequently applied through the appropriate fares elasticity to estimate the reduction (increase) in demand due to greater (lesser) crowding. These PDFH crowding penalties reflect a particular type of rolling stock.

  The current DfT approach is to take the PDFH crowding penalties as a starting point and build upon them to produce a more suitable set of crowding penalties for the purpose of demand forecasting. This entails adjusting the PDFH crowding penalties for different rolling stock designs; extending the table to higher load factors and converting the monetary penalties into factors on journey time. Please note this is interim guidance, since the DfT is actively reviewing the preferred approach to modelling crowding and more detail will be available in due course.

  Once the crowding penalties have been calculated a journey time (JT) elasticity must be applied to determine the demand impact of crowding. Note the PDFH Generalised Journey Time (GJT) elasticities are inappropriate for this calculation since they refer to the whole GJT including interchange and frequency considerations, whereas the above crowding penalties refer to in-vehicle journey time only. The journey time elasticities DfT currently uses in crowding modelling have been derived from the PDFH GJT elasticities in Tables B3.2-B3.6 and are listed as follows:

  - London / SE: -0.455
  - Intercity: -0.72
  - Other: -0.54

  Since the journey time elasticity will vary by route according to the proportion journey time forms of GJT, different journey time elasticities may be more appropriate. If there is sufficient supporting evidence alternative elasticities for specific geographical areas/routes may be used.

  By its very nature, observed rail demand may already be subject to crowding. Consequently, to model the impact of crowding on demand over time the crowding impact, as calculated above, implied in the observed demand data should be used to calculate the level of unconstrained demand. This is the level of demand if there was no constraint on capacity and hence no crowding. From this, the level of unconstrained demand should be forecast over the appraisal period, using exogenous growth rates of demand for the services modelled.

  To calculate the impact of crowding at a specific time in the future, crowding penalties should be calculated for the level of unconstrained demand at that point of time and the resulting demand impact applied to return to a level of constrained demand. This can be achieved through an iterative process that calculates the final level of constrained demand, given a set of crowding penalties. For example, there is a train with one hundred passengers of unconstrained demand. The crowding penalties experienced on this train cause fifty passengers to be crowded off leaving fifty individuals remaining on the train. However, with fifty passengers now on the train the level of crowding penalties experienced falls and thus some of those who were crowded off the train would return to the train. Yet, once these passengers get back on the train the level of crowding penalties changes once again and consequently some of those who returned to the train will leave the train. This process continues until reaching a stable equilibrium. Note, if this final level of demand is at a point above the crush capacity of the service then this should be scaled down to the crush capacity.

Alternatively, this can be achieved through a pre-determined crowding curve, with a relationship between the level of unconstrained demand and constrained demand, given a set of crowding penalties. It is also desirable, although complex, to model the interaction of passengers between trains given differing levels of crowding on different trains over time.

If you require any further advice on this approach contact the Rail Technical and Professional directorate of the DfT.

6. Sensitivity tests

6.1.1. Since PDFH version 4.1 was released in June 2005 a significant amount of primary research has been undertaken into elasticity-based passenger demand forecasting. In light of this work, DfT recently commissioned a review of the current PDFH approach and asked for recommendations for short term improvements to the existing forecasting methodology. Further testing is required to establish the explanatory capability of the proposed amendments. However, in some areas we feel sufficiently confident that the adjustments should be incorporated as sensitivity tests when carrying out demand forecasting. Sensitivity tests should be applied in the areas described below. Further explanation of the recommended parameters and methodology are set out in annex 1.

- **Income (GVA per capita) elasticities** – Use the revised GVA per capita elasticities. These replace the current interactive distance term with individual elasticity estimates split by distance band.
- **Conditional fare elasticities**[1] - Use recommended conditional elasticities as basis for any analysis of changes to fares, using evidence of diversion factors and market share to generate own and cross elasticities.

7. DfT Forecasting Requirements

7.1.1. All DfT Rail and National Networks forecasting applications are required to adhere to the forecasting methodology set out above. Submissions need to be accompanied with a demand forecasting methodological paper which includes sources used and assumptions clearly stated. In addition, sponsors can apply alternative forecasting methodologies and driver growth forecasts where it is believed these provide improved forecasts.

[1] Conditional elasticities measure the change in demand for a service in response to a change in its price and/or journey time, conditional on the same change having taken place on an alternative service e.g. the change in demand for a bus service if the price on that service, and a competing rail service, both increase by 5 per cent. Alternatively, conditional elasticities may relate to all tickets on the same service e.g. single, return, season etc. increasing.

7.1.2. Alternative methodologies and driver forecasts could include different parameter estimates which are believed to better reflect the specific region, TOC or flow but could also be less formal adjustment where the PDFH approach does not provide credible forecasts based on historic experience. There may also be alternative assumptions in demand driver growth, such as employment, population, GDP, car ownership, car journey time etc. Alternative forecasting methodologies and growth factor/driver assumptions need to be agreed with DfT T&P and demonstrated in addition to the guideline approach.

7.1.3. Notwithstanding the above, TEMPRO planning data (population, employment, households etc.) should act as control totals at a suitable spatial level. Any changes, when scaled up to a wider level should show no net overall change in growth factors when compared with TEMPRO. An example is where it is believed growth in employment immediately around a station is greater than reflected in TEMPRO zone forecasts and local evidence is applied to amend the employment factor accordingly. In this case the overall control total would be expected to remain unchanged, i.e. no overall net growth across the wider area, such as district or county. In practice there is scope to relax this restriction to wider geographic areas, but such alternative approaches should be discussed and agreed with both ITEA and T&P before proceeding. Further guidance on the use of TEMPRO data and the application of TEMPRO growth factors can be found in Web-TAG Unit 3.15.2.

8. Further Information

For information on:	See:	Location:
Passenger Demand Forecasting Handbook (PDFH)	*Billy Denyer – ATOC (billy.denyer@atoc.org)*	-
General transport modelling	*Summary advice on modelling*	TAG Unit 2.4
Variable demand modelling	*Variable Demand Modelling Guidance*	TAG Units 2.9 and 3.10
Rail appraisal	*Guidance on Rail Appraisal*	TAG Unit 3.13
Treatment of uncertainty	*The Treatment of Uncertainty in Model Forecasting*	TAG Unit 3.15.5
The Network Modelling Framework (NMF)	NMF Background Documentation	DfT web site
Use of the TEMPRO software	TEMPRO user guide	TEMPRO download site
Use of TEMPRO data	*Use of TEMPRO data*	TAG Unit 3.15.2
National Rail Travel Survey	NRTS Provisional Report	DfT web site
MVA Rail Passenger Demand Forecasting Research	Published reports	DfT web site

9. References

ATOC (August 2002), *Passenger Demand Forecasting Handbook (version 4.0)*

ATOC (June 2005), *Passenger Demand Forecasting Handbook (version 4.1)*

Department for Transport (July 2007), *Delivering a Sustainable Railway: White Paper*

Faber Maunsell | AECOM (July 2007), *Saver Fares: Differentiation and Potential Deregulation*

MVA Consultancy (May 2006), *Review of London Fares Elasticity*

MVA Consultancy (March 2007), *Rail Passenger Demand Forecasting Research*

MVA Consultancy (November 2007), *London Fare Elasticity Study*

Wardman M (March 2007), *Analysis of London-Based and South East Flows to Support MVA's Interim Demand Forecasting Methodology*, Institute for Transport Studies, Leeds University

Wardman M and Dargay J (March 2007), *External Factors Data Extension and Modelling*, Institute for Transport Studies, Leeds University

10. Document Provenance

This Document was produced in April 2008 to provide guidance on the estimation of elasticity-based passenger demand forecasts for rail. Paragraph 1.1.3 was updated in December 2008.

This Unit became definitive guidance in April 2009.

Technical queries and comments on this TAG Unit should be referred to:

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11. Annex A: Applying the sensitivity tests

11.1. Income (GVA per capita) elasticities

The recommended income elasticities are provided in table 2 below

	from London	to London	non London
London TCA	1.3	1.3	1.3
South East	1.2	1.2	1.2
Rest of country <20 miles	n/a	n/a	1.2
Rest of country 20-80 miles	n/a	n/a	1.2
Intercity 80-130 miles	0.7	2.0	1.2
Intercity >130 miles	1.7	1.4	1.2

Table 2: Recommended elasticities to GDP per capita (non-seasons)
Source: MVA, *Rail Passenger Demand Forecasting Research*

11.2. Conditional fare elasticities

Data permitting it is recommended that the best way of assessing any change to fares is to start with conditional elasticities (as they should be broadly independent of the competitive situation and are therefore relatively stable) before applying diversion factors and market shares to calculate own and cross-elasticities. Table 3 presents recommendations on conditional elasticities.

	Seasons	Other	Commute	Business (full/reduced)	Leisure (full/reduced)
London Travelcard Area (LTA)	-0.2	-0.5	-0.2	(-0.4/-0.65)	(-0.6/-1.1)
South East to LTA	-0.3	-0.7	-0.3	-0.3	-0.9
LTA to South East	-0.55	-0.7	-0.55	-0.3	-0.9
Rest of country to/from LTA	-0.7	-0.95	-0.7	-0.75	-1.05
Non London: PTE <20miles	-0.4	-0.55	-0.4	-0.4	-0.6
Non London: non-PTE <20miles	-0.5	-0.7	-0.5	-0.5	-0.75
Non London : Inter urban >20miles	-0.7	-0.75	-0.7	-0.55	-0.9
Airport (non Heathrow)	-0.5	-0.5	-0.5	-0.4	-0.6

Table 3: Recommended conditional fare elasticities – all public transport fares changing

Full commentary for these recommendations is provided in the *Rail Passenger Demand Forecasting Research* and, for the London Travelcard Area, *London Fare Elasticity* Study.

Typical own elasticities are provided in table 4, although it is recommended that these are calculated from diversion factors if these are known.

	Seasons	Other	Commute	Business (full/reduced)	Leisure (full/reduced)
London Travelcard Area (LTA)	-0.35	-0.75	-0.35	(-0.8/-0.65)	(-1.3/-1.1)
South East to LTA	-0.35	-0.8	-0.35	-0.35	-1.05
LTA to South East	-0.6	-0.8	-0.6	-0.35	-1.05
Rest of country to/from LTA	-0.75	-1.05	-0.75	-0.8	-1.25
Non London: PTE <20miles	-0.6	-0.85	-0.6	-0.5	-0.9
Non London: non-PTE <20miles	-0.7	-1.0	-0.7	-0.6	-1.05
Non London : Inter urban >20miles	-0.8	-1.0	-0.8	-0.6	-1.1
Airport (non Heathrow)	-0.7	-0.7	-0.7	-0.5	-0.9

Table 4: Typical own fare elasticities – other public transport fares held constant