Department for Transport

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Forecasting and Uncertainty

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This TAG Unit is guidance for the **MODELLING PRACTITIONER**

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7.5.4 In some cases it may be desirable to make simplifications in the modelling, particularly for public transport schemes. Such uncertainty should be considered, although removing the simplifications altogether would defeat the purpose of the simplification. It is recommended that:

- where simplifications in network coding cannot be clearly supported by the modeller's previous experience, tests should be undertaken of increasing the complexity of the coding in a selection of instances;
- where simplifications in modelling traveller responses have been applied, the analyst should consider conducting one or more tests in which a range of simple factors are applied which are considered to encompass the possible effects of the missing traveller response.

7.5.5 Where public transport is modelled, consideration of the response of existing public transport service operators should form part of the appraisal of the new scheme. New public transport services may well extract patronage from existing public transport modes, which can result in a reduction in operating surplus or an increase of operating subsidy to unacceptable levels. It is not necessary to attempt to rectify this by adjusting the design within the scheme forecasting process, but the Promoter may wish to include such adjustments as part of the scheme.

7.5.6 As changes in cost between the Without-Scheme Forecast and the With-Scheme Forecast will be used directly in the appraisal of the scheme, accuracy of the scheme representation is **even more crucial** than accurate representation of other changes to the network between the base year and Without-Scheme Forecast.

8 Modelling a Scenario – Rail Schemes

8.1 Introduction

8.1.1 The **Passenger Demand Forecasting Handbook** (PDFH) provides the general framework for forecasting rail passenger demand. It summarises collective rail industry knowledge of the effect of various influences on passenger demand, and draws forecasting parameters from previous experience and research. It also provides guidance on applying this knowledge to the preparation of passenger demand forecasts.

8.1.2 PDFH is maintained and developed by the Passenger Demand Forecasting Council (PDFC), which consists of all the Train Operating Companies, Network Rail, Department for Transport, Transport Scotland, the Office of Rail and Road, Transport for London and the Passenger Transport Executives Group and other devolved bodies. It procures research into demand forecasting issues relevant to the rail industry[1].

8.1.3 In order to remain state-of-the-art, the PDFH is periodically updated to incorporate the findings from recent peer reviewed primary research. TAG rail forecasting guidance is an amalgam of the recommendations in PDFH and some references to DfT specific research.

8.1.4 .The most effective structure for forecasting rail schemes is an elasticity-based model, in contrast to the approach used for other surface schemes. TAG guidance is based on the PDFH and used elsewhere within the rail industry, but with a small number of amendments to reflect the strategic and longer term forecasting needs of DfT. Applications of the methodology include:

- strategic planning - including use of the Network Modelling Framework (NMF);
- franchise analysis - specification, bid assessment, ad-hoc initiatives;
- financial forecasts - forecasting Train Operating Company (TOC) revenue; and

1 Further information on PDFC and PDFH can be found at https://www.raildeliverygroup.com/pdfc.html

- option appraisal - of programmes, projects and policies.

8.1.5 All rail passenger demand forecasts that are submitted to DfT for funding are required to adhere to the methodology set out in this section. As a consequence funding applications need to be preceded by a demand forecasting methodological statement which clearly states the data sources, assumptions and methodology used. This should be incorporated within the Appraisal Specification Report.

8.1.6 There are a small number of circumstances where alternative approaches may be more appropriate. Section 8.2 distinguishes between the two principal approaches to modelling rail passenger demand and describes how the most appropriate approach should be determined. Where this is proposed, the suggested methodology should be discussed with the Department.

8.1.7 Sections 8.3 and 0 describe how the PDFH approach is used (and varied from) in TAG, and section 0 provides conclusions.

8.2 Establishing a Demand Forecasting Approach

8.2.1 As noted in TAG Unit M1.1, rail passenger demand can be modelled either using an elasticity based model or a variable demand choice model approach. In contrast to highway and local schemes, however, the elasticity based model approach is most commonly used for rail schemes, because:

- it is often difficult and expensive to collect sufficient data of adequate quality to construct a choice model for rail schemes, which usually cover a large geographical area;
- rail is a minority mode, and so its demand is not expected to be constrained in proportion with population growth in the same way as more common modes, such as car or walk.

8.2.2 Elasticity based models also have the advantage of being simpler to build, maintain and use than variable demand choice models.

8.2.3 However, if a variable demand choice model of the area already exists, it can be used to appraise rail schemes using the method discussed in section 7. Variable demand choice models can also be useful where rail services are in direct competition with another mode (e.g. a major road parallel to a railway route). Variable demand or choice models may also be appropriate to applications where there is a very large change in supply or there are no direct services or little demand on the services at present. In addition gravity models may also be appropriate for these cases. Finally for new stations alternative models should be considered[2].

8.2.4 The remainder of this section describes the own-cost elasticity approach, which determines 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 previously using the unimproved service, and the scale of change in service quality delivered by the new rolling stock.

8.3 Using the DfT Forecasting Methodology

8.3.1 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 rail TAG/PDFH approach covers 10 exogenous growth factors/drivers as described below. These factors are also included in the Demand Driver Generator (DDG) set of

[2] See https://www.gov.uk/government/publications/passenger-demand-forecasting-for-third-party-funded-local-rail-schemes

inputs which are available on request for work being done on behalf of the DfT. The DDG set of drivers is designed to be used in the EDGE[3] forecasting tool which has been developed to implement rail forecasting elasticities and assist in producing exogenous demand forecasts.

- GDP
- Employment or EmpIndex (a new variable in the RDFE[4] study and PDFH 6 that combines employment with socioeconomic factors)
- Population or PopIndex (a new variable in the RDFE[4] study and PDFH 6 that combines population with socioeconomic factors)
- Car Costs
- Car Journey Time
- Bus Cost
- Bus Journey Time
- Bus Headway
- Underground Cost
- Air Passengers

8.3.2 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 given below.

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

8.3.3 GDP Series: In 2012 the composition of the GDP deflator was altered which increased real GDP growth. For the GVA per capita elasticities in earlier versions of PDFH, adjustments have been made to forecast growth rates to account for this fact. These adjustments are no longer required when using the elasticities in the Rail Demand Forecasting Estimation (RDFE) study[4] or PDFH6.

8.3.4 The application of incremental demand techniques requires detailed information on the level of demand in the base year (to which the increments are then applied). LENNON[5] ticket sales data are

3 EDGE (Exogenous Demand Growth Estimator) is a flexible model developed by DfT that allows user to enter customised driver growth forecasts and elasticity parameters, as well as to choose any zoning system. EDGE can be made available free of charge to anyone. Please contact the DfT for the latest version of EDGE.

4 The Rail Demand Forecasting Estimation (RDFE) study is a DfT commissioned study by Systra, Leigh Fischer and RAND into forecasting and some of the recommendations in PDFH 6.0 are based on it https://www.gov.uk/government/publications/rail-demand-forecasting-estimation-study-phase-reports

5 LENNON (Latest Earning Networked Nationally Over Night) is the rail industry's ticket sales database through which the vast majority of the rail ticket data is processed. Due to commercial confidentiality requirements access to the LENNON system is restricted to train operating companies and a handful of other organisations.

typically used 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[6].

8.3.5 When using raw Lennon data there are some gaps in the station to station matrix for UK rail trips. In particular there are significant gaps in travel within urban areas due to the large proportion of journeys which are carried out on cross-modal Travelcard products. Adjustments to account for these trips and for London trips using Travelcard products are now available in the Moira 1 and Moira 2.2 base matrix.

8.3.6 In the base matrix or base data in the analysis, the analyst will need to ensure that the assumptions about how many journeys are made with each season ticket are correct. The recommendation from the Journeys per Season Ticket Study[7] should be used unless better local evidence is available. These recommendations are available in the TAG Data Book tab M4.2.5. In due time, it is possible that these will be added into the standard base matrix in many models and could be included in Lennon itself. In the meantime, adjustments should be made in the base matrix by dividing by the old assumptions (10.3 for a weekly, 46 for a monthly and 480 for an annual) and then multiplying by the new assumptions. For high level national analysis, it is acceptable to use the national recommendations but when the analysis is detailed or concentrated on specific flows the flow category and distance band breakdowns should be used. It should also be noted that when the original source of the journeys does not use the Lennon factor (such as London and some PTE infills) then these recommend values do not apply and the Moira values should instead be used.

These values are given in:

M4.2.5: Average rail journeys per season ticket

8.3.7 The **Without-Scheme forecast** can be defined according to exogenous factors outside the control of government and train operators, including any committed initiatives (endogenous drivers) which are due to be implemented during the forecast period.

8.3.8 At least one **With-Scheme forecast** will also be required. These should retain the same exogenous growth characteristics of the Without-Scheme case, but also include any changes in endogenous factors specific to the intervention under scrutiny. Examples include service enhancements, fare changes and rolling stock improvements.

8.3.9 A range of software tools are available to assist the practitioner in producing forecasts of rail passenger demand. Of these, EDGE and MOIRA deserve special attention.

8.3.10 The impact of timetable changes (represented as changes to GJT) upon rail demand are generally modelled using MOIRA. Moira 2.2 allows for the modelling of timetable changes incorporating crowding impacts.

8.3.11 Forecasts should use the sources of data as recommended in TAG unless there is sufficient good-quality evidence to suggest otherwise. As ever, any divergence from standard assumptions must be discussed with DfT prior to implementation, and should be fully described within the Appraisal Specification Report.

8.3.12 Forecasting parameters should be taken from the TAG Data Book and PDFH 6.0 and 5.1 as set out in Table 1.

6 MOIRA is a software tool that models the impact of timetable changes on both the overall rail market, and individual train operating companies. It is available to full members of the Passenger Demand Forecasting Council (PDFC) and, with permission, third parties working on their behalf. The data in MOIRA is based on LENNON with uplifts for those areas where LENNON does not provide adequate coverage.

7 Further information on the publication is available here: https://www.gov.uk/government/publications/rail-journeys-per-ticket-study

Table 1 PDFH Recommended Forecasting Parameters

	TAG Data Book / PDFH Version	Chapter	Tables	Notes
Journey purpose/ticket type splits by flow category	See TAG Data Book table A5.3.2	N/A		See TAG Data Book
External Environment Excluding intra London Travelcard area and airports	TAG Data Book table M4.2.4 and text below	N/A		See 8.3.12 – 8.3.13
External Environment – Intra London Travel card area and airports	6.0	B2	B2.1 and B2.5	See 8.3.14 – 8.3.17
Inter Modal Competition	6.0	B2	B2.1- B2.5	See 8.3.18 -3.19
Fares	6.0	B3	B3.1 to B3.7	See 8.3.20 – 8.3.22
Generalised Journey Time (GJT) elasticities	5.0 for airport flows, otherwise 6.0	B4	6.0: B4.2 – B4.6 5.0: B4.6	See 8.3.23
Service Interval Penalties	6.0	B4 and C4	B4.10 and section C4.5.4	See 8.3.24
Interchange	6.0	B4	B4.13 unless above elasticities not used in which case B4.15	See 8.3.25
Performance	6.0 (except for large changes)	B5	B5.1	See 8.3.26
Crowding	6.0	B6	Formula above table B6.1	See 8.3.27
Rolling Stock	6.0	B7	B7.1 (apart from seating layout)	See 8.3.29 – 8.3.32
Station Facilities	6.0	B8	B8.1	See 8.3.33 – 8.3.36

Journey purpose/Ticket type splits

8.3.13 As part of the Rail Demand Forecasting Elasticities (RDFE) study,[8] journey purpose / ticket type splits by flow category have been estimated from NTS data. These are constrained to LENNON ticket sales data.[9] The NTS is an annual survey of households and contains a relatively small sample of rail trips given rail trips are only around 2% of total domestic trips. However, by aggregating the evidence from 2005 and 2014 and aggregating up to PDFH flow category level, the sample sizes are large enough for the estimated splits to be robust (between 1,200 and 17,000 rail trips by flow category).

8.3.14 Where more disaggregated or more recent data is available (for example flow level NRTS data) or a more up to date local survey that may be used instead.

External Environment

8.3.15 For external factor forecasting for all flow categories apart from within the London Travelcard area and airport stations the recommendations from the RDFE study should be used. These are presented in the TAG Data Book Table M4.2.4.These are broadly the same as the recommendations in PDFH6 apart from for EmpIndex elasticities for to and from cities outside of London where PDFH 6 recommends lower elasticities. Our guidance is that the RDFE elasticities in the TAG Data Book should be used[10].

8.3.16 The GJT trend (a reduction in the value of GJT of 1% per year compounding) was used in the RDFE study regressions (apart from for season tickets between the Network South East area and London), and we believe this is partly accounted for by endogenous quality changes over the estimation period. So, where any quality endogenous improvements are separately forecast (such as mobile connectivity, station improvements, rolling stock enhancement, marketing, branding or fare policy) then we recommend this GJT trend is not used in forecasting. For strategic forecasts that do not separately account for those endogenous quality features we recommend that the GJT trend is used in full up to the year 2030/31 in the central case. In the latter case, we recommend that sensitivity tests are run with no GJT trend and with a GJT trend that ends in the final forecast year.

8.3.17 For flows within the London Travelcard area and flows to and from airports we recommend that the PDFH 6 parameters are used and no GJT trend is applied.

Inter Modal Competition

8.3.18 To model the impact of car competition on rail demand, car cost, car ownership, and car time should be used. It is recommended that car cost variable is defined as the perceived cost per km – as described in Values of Time and Operating Costs (TAG Unit A1.3 – User and Provider Impacts) – to which the PDFH 6.0 car cost elasticity should be applied. A forecast car cost series, car time series and bus time series by PDFH flow category, calculated on this basis is provided in TAG Data Book M4.2.2 – Car cost series for rail demand forecasting. This series is provided for financial years in index form (2010/2011 = 100) and represents the real change in car costs per kilometre, combining changes in fuel prices, vehicle efficiency, fleet mix and forecast speeds. Where PDFH 6.0 elasticities are used, the CPI real version of these car cost forecast should be used and CPI real forecasts of bus cost forecasts should also be used.

8.3.19 Although PDFH 6.0 does not recommend specific air cost and air headway elasticities, practitioners should still model the impact of these factors on rail flows where there is air competition. London Underground RPI real forecasts should be used to be compatible with rail fare assumptions.

8 https://www.gov.uk/government/publications/rail-demand-forecasting-estimation-study-phase-reports

9 Lennon is the UK rail industry's central ticketing system. Further information is available at: https://www.gov.uk/government/publications/rail-passenger-miles

10 If it can be demonstrated that you are using an employment forecast which would have anticipated the high employment growth in the centre of cities over the last two decades then you may be justified in using lower EmpIndex elasticities (see guidance in PDFH6.0).

Fares

8.3.20 The elasticity recommendations in Chapter B3 of PDFH 6.0 should be applied to high level assumptions regarding changes to fares. This means an overall change which is applied across all ticket types. For anything more complex and detailed than an overall fares change a bespoke fares model should be considered[11]. In line with PDFH 6.0, RPI real fare forecasts should be used in conjunction with these elasticities.

8.3.21 When modelling the impact of high level fare changes it should be assumed that the broad basket of fares changes at the same rate as the regulated fares. It should be ensured that the assumption on regulated fare changes is in line with latest regulated fare policy. If you are unsure as to what this is please check with the Department for Transport.

8.3.22 For large changes in fares, the standard constant elasticity functional form may not be appropriate (as discussed in PDFH 6.0 B3.1). In these circumstances it may be sensible to consider alternative functional forms; appropriate guidance on these can be found in PDFH 6.0 D2.

Generalised Journey Time

8.3.23 The option settings in MOIRA which are closest to the guidance requirements should be used. Where there are significant airport flows and/or changes to service to airports MOIRA should not be used and alternative modelling approaches should be discussed with the Department.

8.3.24 The representation of the service interval penalty in Moira and Moira 2.2 is preferred as it accounts for irregular service patterns. For simple analysis the values given in PDFH 6.0 table B4.10 may be used.

8.3.25 Whenever standard PDFH 6.0 GJT elasticities are used, the standard PDFH 6.0 interchange penalties (PDFH 6.0 table B4.13) should be used as the GJT elasticities have been estimated using the standard interchange penalties. However, where different elasticities have been used or non-elasticity based model (such as a gravity model or a mode choice model) has been applied then a new set of interchange penalties based on more recent information should be used (PDFH 6.0 table B4.15). These interchange penalties only cover non commuting tickets so the standard ones still need to be applied for season tickets. The table B4.15 interchange penalties should also be used as a sensitivity test in cases where standard GJT elasticities have been used and the removal or creation of interchanges is important to the scheme.

Crowding

8.3.26 Practitioners can choose their own approach to modelling crowding as long as it is consistent with PDFH 6.0 recommendations. It should be noted that Moira 2.2 has been developed to provide allocation in a way to take account of the crowding of services.

8.3.27 Performance: PDFH 6.0 moves to a direct demand response to performance using constant elasticities. These should be applied to measure the impact of demand changes but only for proportional changes of less than 25% of Average Performance Minutes (APM). For larger proportional changes other functional forms should be used and discussed with the Department. PDFH 6.0 values cannot be used to measure benefits per passenger and instead the ratios in PDFH 5.1 should continue to be used for that passenger see TAG Unit A5.3 – Rail Appraisal.

Final Forecast Year

8.3.28 Details of the Final Forecast year are in TAG Unit A5.3 – Rail Appraisal.

11 Details on how to use own and cross elasticities or fares choice models are provided in PDFH 6.0 chapter D13

Rolling stock

8.3.29 PDFH 6.0 B7 recommends that the demand impact of rolling stock quality is determined as a weighting on in-vehicle time. Whilst the Department recommends using the values attributed to rolling stock improvements, it is worthwhile clarifying how DfT expect these values to be applied. In particular, how the without-scheme scenario should be specified.

8.3.30 Firstly, promoters must describe their without-scheme scenario as carefully as possible. The market for rolling stock is active and has orders for new carriages, stock cascades and refurbishments taking place on a regular basis. Over the appraisal period the Department for Transport would therefore expect improvements to rolling stock to take place regardless of any specific initiative. This gradual process of improvement must be reflected within the appraisal base-case and only the net demand impact should be attributed to the specific intervention being considered. For example, if a particular proposal brings forward rolling stock improvements by five years (on an identical basis) the benefits attributable to the intervention can only last for this period of time.

8.3.31 Secondly, careful consideration of the dynamic impact of new or refurbished rolling stock should be made. The Oxera report **How Long do the Impacts of New Rolling Stock Last?** (Feb 2009) suggests that there is considerable variation in the scale, nature and durability of demand uplifts due to rolling stock changes. When submitting a proposal that involves changes to rolling stock, promoters should explicitly state how they have determined the most appropriate profile of demand response to be used.

8.3.32 In doing this it is important that due care and attention is paid to the text accompanying table B7.1 in PDFH 6.0. This provides important contextual information that should be considered when determining the appropriate value of time multiplier to be applied. Since qualitative judgement regarding the current and future level of rolling stock specification introduces risk to the cost-benefit analysis process, a full justification for the uplifts used must be provided. It should be noted that the Department would expect improvements to rolling stock to exhibit diminishing marginal returns to investment and for package effects from investment across multiple rolling stock attributes to be observed (as reflected in PDFH 6.0).

8.3.33 Where the seating layout values are used we recommend that the distance bands from the original study AECOM "Demand impacts of seating layouts for rolling stock on commuter routes"[12] are used, rather than the standardised ones in the PDFH 6.0 table.

Station facilities

8.3.34 PDFH 6.0 recommends direct demand uplifts from improvements to a range of station facilities. However, care should be taken when determining the appropriate base demand to which uplifts should be applied. As with the Department's recommendations regarding rolling stock modification, it is imperative that a full justification of the demand uplifts and base demand to which these apply is provided. Once again, due care and attention must be paid to the text accompanying table B8.1 in PDFH.

8.3.35 In light of previous revealed preference evidence[13] the Department retains its previous recommendation that total long-term net demand uplifts (i.e. after the impact of abstraction has been taken into account) above 2% are unlikely and would need detailed justification. This restriction is intended to provide a simplified representation of a range of factors that may suppress the demand uplift from station enhancements.

8.3.36 For example, the Department would expect improvements to station facilities to exhibit diminishing marginal returns to investment and package effects (as reflected in PDFH 6.0). The Department

[12] Available from RDG's website for PDFC members https://www.raildeliverygroup.com/pdfc.html .

[13] See: The Effects of Station Enhancements on Rail Demand – Phase 2 Final Report (2008); University of Southampton, Accent Market Research and Institute for Transport Studies – University of Leeds

would also expect to observe both a period of demand ramp-up and subsequent decay as passengers adjust their expectations of incremental station upwards. In practice the demand uplift generated by station enhancements may exceed the 2% cap in the short to medium term. However, over the entire appraisal period the maximum uplift would be expected to be binding.

8.3.37 Finally, there are close linkages between chapters **B8 Station Facilities** and **B9 New and Competing Services and Stations** in PDFH 6.0. Many of the improvements to access set out in table B9.4 may also be considered as station enhancements e.g. secure parking. Promoters are therefore advised to read both chapters in conjunction and to be careful to avoid double counting.

Sensitivity Testing, Uncertainty and Scenarios

8.3.38 Rail demand forecasting is inherently uncertain so presenting the uncertainty around our forecasts is essential. Where there is particular uncertainty around an input parameter this must be presented as a sensitivity test (see guidance above on when this applies to the GJT trend and interchange penalties). Where there is also uncertainty about a driver, specific uncertainty tests should also be used.

8.3.39 In addition to carrying out sensitivity tests, ways should be considered of presenting broader uncertainty. The Department has developed a tool called the Rail Uncertainty Model (RUM) that represents top down demand forecasting uncertainty. This is available upon request for work done on behalf of the DfT. Alternative scenarios based on possible future states of the world may also be of interest for large projects.

8.4 DfT Forecasting Requirements

8.4.1 All rail passenger demand forecasts that are submitted to DfT for approval are required to adhere to the methodology set out in this document. However, exceptions may be permitted where any of the following apply:

- superior parameter estimates exist that better reflect the specific region, TOC or flow under scrutiny;
- the recommended methodology is proven not to provide credible forecasts based on historic experience; and
- alternative forecasting methodologies are considered more suitable to the specific circumstances (see section 8.2 of this TAG unit and chapter B9 of PDFH 6.0).

8.4.2 Any divergence from the forecasting methodology set out in this document must be supported by appropriate, robust evidence in favour of the change. This should be described within the Appraisal Specification Report (see TAG Guidance for the Technical Project Manager) alongside a clear statement of the data sources, assumptions and demand forecasting methodology to be used. We strongly recommend that the forecasting approach is discussed with DfT prior to carrying out any detailed programme of work.

8.4.3 This Unit has been updated following publication of version 6.0 of the Passenger Demand Forecasting Handbook (PDFH) and the RDFE study and will continue to be updated in light of new evidence. However, practitioners should keep abreast of emerging evidence to ensure they can respond to changes as soon as they are implemented.