February 2022

HS2

PLANET Framework Model PFMv10a

Step Through Report

Department
for Transport

High Speed Two (HS2) Limited has been tasked by the Department for Transport (DfT) with managing the delivery of a new national high speed rail network. It is a non-departmental public body wholly owned by the DfT.

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1 Overview

1.1 Introduction

1.1.1   This document outlines the incremental effect of changes in the modelling assumptions and approach to developing analytical inputs for the Update on the Strategic Outline Business Case (SOBC) for the Phase 2b Western Leg of the HS2 scheme.

1.1.2   This report provides a summary of the key changes made to the modelling approach and analysis that supports the assessment of the Economic Case for HS2 since the Phase One Full Business Case (Ph1 FBC) was published in April 2020, and the effect of these updates on the appraisal of the scheme. This document is one of a series that provides explanation and analysis of the evidence which underpins the economic appraisal of the HS2 scheme.

1.1.3   As with any scheme, the Economic Case for HS2 will evolve over time and be influenced by many factors including:

- changes to the design of the scheme;
- external factors such as economic or population forecasts, changes in rail services in the future etc; and
- industry guidance on passenger demand forecasting and appraisal of transport schemes.

1.1.4   The PLANET Framework Model (PFM) has been developed by HS2 Ltd as a modelling tool to forecast the demand and economic benefits of the HS2 project. The most recent version of PFM is PFM version 10a (PFMv10a, also referred to as PFMv10.1). Since the Ph1 FBC, HS2 Ltd has continued to develop and update modelling assumptions from the wider rail industry, update economic appraisal tools, and improve the evidence on current and future patterns of passenger demand. There have also been developments in the modelling and appraisal practice that have been incorporated into the Department for Transport (DfT)'s Transport Analysis Guidance (TAG).

1.1.5   These changes have been incorporated into the analysis supporting the updated Phase 2b Western Leg SOBC. This document outlines the impact that the changes have had on the forecast benefits and revenues for the Phase 2b Western Leg of HS2.

1.2 Western Leg

1.2.1 Throughout this report, several modelled scenarios from the PFM are referred to:

- **Do Minimum**: In this scenario there is no HS2 scheme and this forms the reference case against which the benefits and revenues of the various HS2 phases are assessed;
- **Phase 2a**: In this scenario, we assume that the high-speed rail network has been delivered from London Euston to Birmingham and Crewe with some high-speed services using the conventional rail network for on-ward travel; and
- **Phase 2b Western Leg (WL)**: In this scenario we assume the high-speed rail network is extended from Crewe to Manchester Piccadilly (the Western Leg) with significant expansion of high-speed services.

1.2.2 Full details of service patterns and modelling assumptions for each of these scenarios is included in the PFMv10a Assumptions Report.

1.2.3 The Value for Money (VfM) assessment focuses on the case for the Western Leg of Phase 2b (from Crewe to Manchester and the North West). It assumes that Phase One and Phase 2a are operational and involves the comparison of modelled benefits and revenues for the Phase 2a and Phase 2b WL scenarios. This will be the first time the incremental value of the HS2 Phase 2b Western Leg has been reported. Hence, the benefits and revenues reported in this step-through represent the incremental value of the HS2 Phase 2b Western Leg only.

1.2.4 This adds a level of complication to reviewing and discussing the impacts of model updates, specifically when attempting to assign benefit and revenues to discrete phases of the scheme which are built incrementally. Some updates to the modelling suite will impact all phases of the HS2 scheme in a similar way (e.g. TAG updates), whereas other updates have different spatial impacts which will affect HS2 phases in different ways (e.g. updates to train timetables for specific Train Operating Companies (TOCs) or rail demand forecasts).

1.2.5 It should also be noted that the PFM is used to forecast passenger benefits and revenues from the HS2 scheme. It is not used to directly forecast capital and operational cost estimates and so these are not outlined within this step-through report.

1.3   Development steps to PFMv10a

1.3.1   The Phase 2b Western Leg has been assessed using a newly developed version of the PLANET Framework Model (PFM) known as PFMv10a (also referred to as PFMv10.1). This has been updated with revisions to modelling assumptions and economic appraisal methods since the release of the previous model version, PFMv9, as used in the 2020 Ph1 FBC.

1.3.2   This document outlines key changes in the assessment of the HS2 Phase 2b WL scheme as a series of steps, from PFMv9 to PFMv10a, setting out the incremental benefit and revenue impact of each update to the modelling suite.

1.3.3   The key changes that have been made to the PFM modelling suite since the previous model release are as follows:

- Step 0: PFMv9 – previous model release;
- Step 1: Revised Station Model Choice (SCM) access costs and updates to supply network assumptions;
- Step 2: Re-basing of demand matrices and service patterns to 2018/19;
- Step 3: Train Service Specification (TSS) update for all Train Operating Companies (TOCs);
- Step 4: New rail passenger demand forecasts;
- Step 5: TAG Databook Updates;
- Step 6: Re-calibration of demand model parameters; and
- Step 7: Revised Phase Opening Schedule

1.3.4   In addition to the above updates to the PFM modelling, new outputs from the DfT's Wider Impacts in Transport Appraisal (WITA) software have been forecast for the Phase 2b Western Leg Increment.

2 Summary of change in benefits and revenues

2.1.1   This chapter shows how the forecast benefits and revenues of the Phase 2b Western Leg Increment are impacted by the updates from PFMv9 to PFMv10a.

2.1.2   It should be noted throughout this comparison that some of the changes in modelled benefits and revenues relate specifically to revised assumptions for the HS2 scheme, while other changes are the result of wider updates to modelling assumptions and methodology. Further details on how each update to the PFM is driving change in forecast benefits and revenues are included in Chapter 3.

Benefits

2.1.3   The change in Net Transport Benefits from PfMv9 to PfMv10a is displayed in Figure 2-1 for the Phase 2b Western Leg Increment. Figure 2-1 shows that the most significant impacts to the forecast benefits of the scheme are the result of lower levels of forecast rail demand, lower rates of growth in values of time into the future (i.e. time savings are of a lower value than in the PFMv9 analysis), and the reduced sensitivity of the demand model following recalibration using more recent TAG guidance, causing fewer new trips and less modal shift from air/road to rail following the introduction of HS2 services.

2.1.4   The other contributors to the change (network updates, rebasing, TSS updates, and changes to the assumed opening schedule) have a more modest impact that largely net out in their impacts on benefits. These inputs vary over time as new assumptions are developed.

Revenues

2.1.5   Ticket revenues are a key component of the business case. Figure 2-2 shows the changes in revenues from PFmv9 to PFMv10a.

2.1.6   Revenues are correlated with forecast levels of passenger rail demand. Figure 2-2 shows that each step of the Phase 2b Western Leg Increment step-through contributes to a reduction in revenue, to varying extents.

2.1.7   The re-basing, demand forecasts, and model re-calibration steps reduce revenues for the Phase 2b Western Leg Increment due to there being fewer additional passengers forecast to use rail services. The updates in the TAG step reduce the forecast growth in rail fares over time, which is the assumed inflation index used for rail revenues, and hence leads to reduced revenues in this step.

The network update step changes the distribution of passengers to stations and services affecting the amount of time passengers spend on trains. Where the journey time savings are lower, because of changes in modelled passenger travel patterns, there is less additional generated revenue. At an aggregate level the Train Service Specification (TSS) update step has only a small negative impact on the revenues in the Western Leg Increment.

Figure 2-1: Change in net transport user benefits and wider economic impacts (£bn) for Phase 2b Western Leg Increment
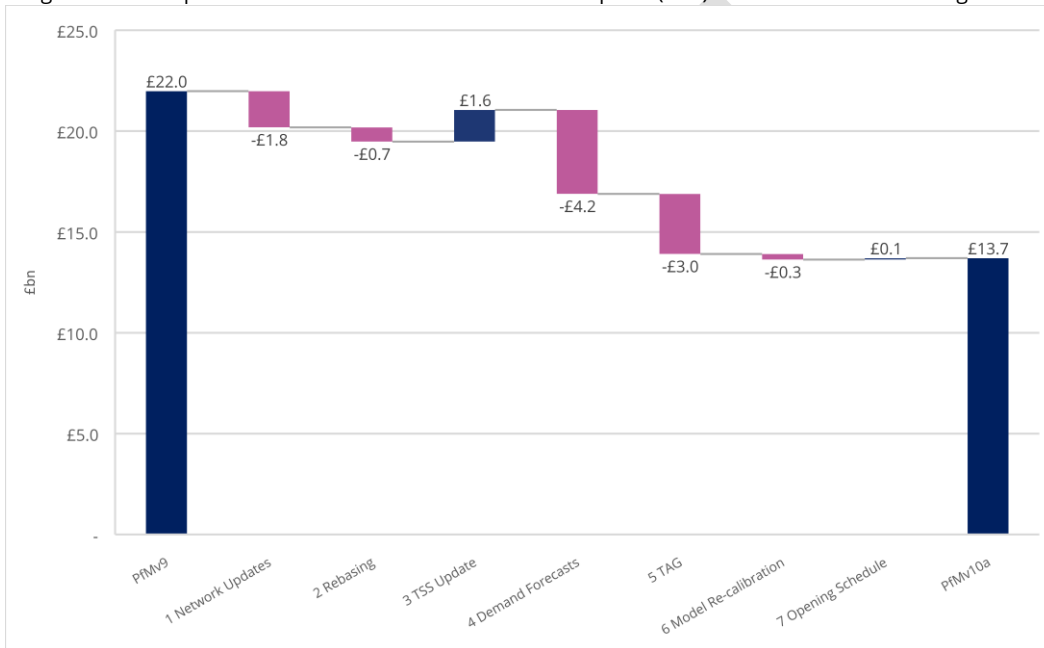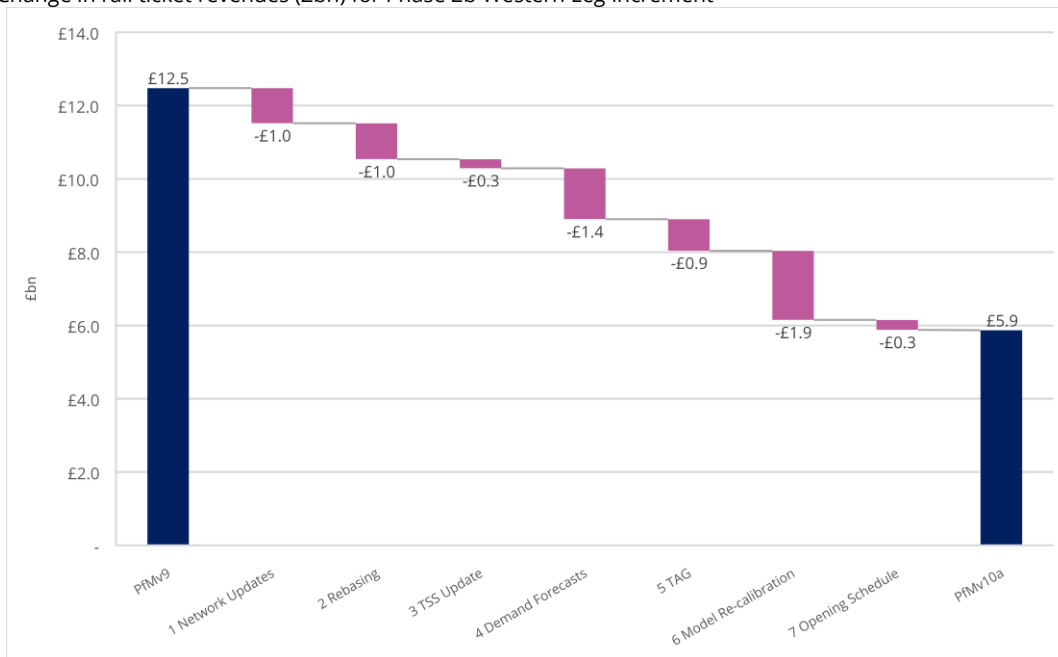

Figure 2-2: Change in rail ticket revenues (£bn) for Phase 2b Western Leg Increment

Detailed benefits breakdown

2.1.8   The overall impact of the updates that have been used in the Value-for-Money assessment of the Phase 2b Western Leg Increment are presented in Table 2-1. This shows the same overall change in benefits and revenues as the step-through charts.

Table 2-1: Quantified benefits for Western Leg Increment for PfMv9 and PfMv10a

Item	(£bn) present value, 2015 prices		
	PfMv9	**PfMv10a**	**Change**
1 Transport user benefits – business	13.2	7,4	-44%
1 Transport user benefits - other	4.5	2.9	-35%
2 Other quantifiable benefits	0.2	0.0	-76%
3 Loss to Government of indirect taxes	-1.1	-0.5	-60%
4 Net transport benefits (PVB)	16.8	10.0	-41%
5 Wider economic impacts (WEIs)	5.2	3.8	-28%
6 Net benefits including WEIs = (4) + (5)	**22.0**	**13.7**	**-38%**
7 Revenues	12.5	5.9	-53%

3 Overview of updates to the PFM

3.1 Step 1: Network updates

Station Choice Model (SCM) update

3.1.1 A complete update in Station Choice Model (SCM) access costs based on latest available data has impacted station usage. For London stations data from Transport for London (TfL)'s Railplan 7.2 model has been used for the base and forecast years, whereas for non-London stations, data from the TRACC database has been used. Overall, the update has had a negative impact on benefits and revenues when comparing Phase 2a and the Phase 2b Western Leg of the HS2 scheme versus the Do-Minimum.

3.1.2 Updating the SCM access costs has changed the distribution of passengers to stations and thus impacts the amount of time passengers spend travelling on trains in the modelling. This reduces the estimated benefits of HS2 due to reduced overall journey times on some of the key flows in the Do Minimum. Hence, the additional time savings when HS2 is introduced are relatively lower than in PFMv9.

Phase 2a reliability modelling

3.1.3 In the development of PfMv9 a new methodology was adopted for modelling reliability. This applied separate delay per kilometre values to each Train Operating Company (TOC), as well as to HS2 services, depending on whether services run on the HS2 captive network, West Coast Mainline (WCML) or East Coast Mainline conventional networks.

3.1.4 Following the completion of PfMv9, it was noted that in Phase 2a the modelled HS2 services between London and Manchester/Liverpool were incorrectly assumed to route via Stafford on the WCML between Stafford and Manchester/Liverpool due to the way the rail network was represented in the Phase 2a PFM coding. The rail journey times were correct, but due to the incorrect routing choice the level of reliability/delay penalty applied was higher than it should have been given the distance the HS2 services will spend on the conventional rail network.

3.1.5 By addressing the inconsistency, the reliability modelling in Phase 2a properly reflects that these HS2 services travel further on more reliable high-speed infrastructure between London and Crewe. This reduced the generalised journey time (GJT) in PFMv10a for HS2 London – Liverpool / Manchester / Lancaster services in Phase 2a by around three minutes compared to PFMv9. This improves Phase 2a benefits and revenues by around 3% relative to the Do Minimum. Due to the way

that the Phase 2b WL network is represented in the model, the trains were correctly routed in PFMv9 and so this change only impacts on the benefits for Phase 2a.

3.1.6   Because the Phase 2b WL services were correctly routed, and this update impacts Phase 2a services only, the benefits of the ~three-minute GJT improvement which in PFMv9 would have been associated with the incremental change between Phase 2a and Phase 2b WL, are now associated with implementing Phase 2a, thus reducing the incremental benefits of the Phase 2b WL.

Heathrow Access Model (HAM) removal

3.1.7   The Heathrow Access Model (HAM), which was originally modelled as part of the early modelling of a HS2 spur to Heathrow airport, has been removed in PFM v10a. The HAM had outlived its intended purpose and added to complexity in the modelling suite. When tested in isolation, removal of the HAM was found to have a negligible impact on PFM outputs and subsequent benefits and revenues.

Pivot process simplification

3.1.8   This allows all model tests to be run from a single 'CORE' version of the model, whereas previously a set of parallel models were used for each modelled phase of the scheme. As with the HAM being removed, this update was tested in isolation and confirmed to have negligible impact on model outputs and therefore scheme benefits and revenues.

3.2   Step 2: Rebasing

3.2.1   To develop rail passenger movements, PFMv9 utilised LENNON ticket sales data from 2014/15 to form its base rail demand matrices. Depending on the current year, the matrices were then uplifted by a global percentage according to the Office of Rail and Road (ORR) average rail growth across the UK during the same period. Where growth in rail demand deviated from the average on certain flows, the matrices did not accurately reflect these differences.

3.2.2   This step involved the rebasing of the demand matrices to accurately reflect rail demand growth at a flow level since the last rebase, moving to a new base year of 2018/19. As part of this update, a more robust methodology was identified, moving away from using LENNON data as the foundations of the matrices to the use of pre-processed MOIRA demand matrices. This removed the requirement to perform cleaning of the LENNON data and Passenger Transport Executive (PTE) area infills from a range of other data sources, which improved consistency with industry standard modelling, as well as reducing the complexity of the rebase.

3.2.3   The highway and air matrices were also updated as part of the rebasing exercise. The highway matrices were previously rebuilt as part of the release of PFMv9 from Highways England (HE) data and have been uplifted to 2018/19 using the DfT's TEMPRO software growth factors. For the air passenger matrices, outputs from the DfT's Aviation Model forecasts were obtained and the volumes interpolated for the new base year.

Impact on Forecast Rail Demand

3.2.4   The rebase of the base year rail passenger demand to 2018/19 from 2014/15 resulted in an overall reduction in future year total rail passenger demand of 5% in both forecast years (2029 and 2041). Some key HS2 flows have higher numbers of forecast rail passengers, whilst others have lower. This is the result of several factors:

- the rebasing exercise updated the passenger travel patterns in the base matrices due to the change in base year, as well as changes in the source data and methodology used for deriving the base matrices;
- the change in base year also impacted on the methodology that was used to forecast passenger demand from the base year to the forecast years because we previously took into account observed growth from ORR data between 2014/15 and 2018/19 before forecasting into the future; and
- changing the model base year also impacted on the supply of passenger rail services in the model base year. For many TOCs, the 2018/19 modelled service patterns are very similar to the future service patterns, given available information about committed infrastructure improvements in the coming years. This means there are now fewer committed rail infrastructure improvements (e.g. the Intercity Express Programme to replace East Coast rolling stock) between the new base year and forecast years. This means that there is less additional capacity in the forecast years, relative to the base year, for the network to accommodate growth in rail passenger demand. As a consequence, a greater volume of forecast growth in passenger demand is constrained by crowding on the rail network.

3.2.5   Despite the reduction in total passenger rail demand across all flows, overall scheme benefits (against the Do Minimum scenario) for both Phase 2a and the Phase 2b Western Leg full network (i.e. Phase One, Phase 2a and Phase 2b Western Leg) increased in this step. This is due to the re-base resulting in an increase in passenger demand along key flows that will be served by these phases of HS2 in the future, such as between London and Birmingham/Manchester, compared with the previous step.

3.2.6   Despite the overall increase in benefits against the Do Minimum scenario, there is a reduction in the incremental benefits for the Phase 2b Western Leg, as Phase 2a benefits increase by 7% in this step, whereas benefits for the Phase 2b Western Leg full network increase by 4%.

3.2.7   This is because, despite an increase in demand between London and Manchester there is a forecast reduction in demand between London and Scotland in this step. For Phase 2a, the increase in London – Manchester demand offsets the reduction in London – Scotland demand. The London – Scotland demand forms a higher proportion of the benefits in the Phase 2b Western Leg scheme and so the Phase 2b Western Leg incremental benefits decrease.

3.3   Step 3: Train Service Specification (TSS) update

3.3.1   Assumptions regarding the level of train service provision in the future are revised annually as TOCs introduce new timetables and services. It is therefore necessary to update modelling assumptions periodically to ensure that our forecast levels of service provision for high speed and conventional rail are in line with latest available information.

3.3.2   Overall, this step results in a small increase in incremental benefits and a small reduction in incremental revenues for the Phase 2b Western Leg. As the HS2 TSS changes have not been tested in isolation, it is not possible to isolate fully the impacts of the conventional rail and HS2 TSS updates. However, analysis suggests that the increased benefits reflect crowding relief from additional seats modelled on the HS2 conventional compatible services and journey time changes for high-speed services.

3.3.3   Reduced revenues are mainly due to improvements in the Do-Minimum supply between London and Scotland. Because the Do Minimum scenario has improved, the relative benefit of HS2 is reduced, and this reduces the volume of new rail trips generated by HS2 which negatively impacts revenues.

3.4 Step 4: Demand forecasts

3.4.1   PfMv9 rail demand forecasts were produced using June 2019 Demand Driver
         Generators (DDGs), which reflected economic and population forecasts published by
         the Office for Budget Responsibility (OBR) in March 2019. The December 2020 DDGs
         used for PFMv10a include a reduction in medium/long term forecasts for population,
         employment, and GDP growth, consistent with OBR forecasts published in 2020[1].
         These include the impact of COVID-19 on employment and GDP, as forecast by the
         OBR in November 2020.

3.4.2   The reductions in the macroeconomic demand drivers have had a negative impact
         on rail passenger demand forecasts. This step reduces the forecast passenger rail
         demand by around 3% in the first forecast year (2029) and by 9% in the second
         forecast year, despite the second forecast year moving from 2039/40 to 2041/42 in
         line with TAG guidance (i.e. incorporating two extra years of growth).

3.4.3   Moving the second forecast year from 2039/40 in PFMv9 to 2041/42 in PFMv10a also
         required producing new air matrices using forecasts from DfT's Aviation Model. Air
         demand increased by around 4% as a result. For highway demand, 2041/42 demand
         matrices were developed by using TEMPRO growth forecasts, resulting in 3% growth
         in highway demand between the 2039/40 and 2041/42 matrices.

3.4.4   The reduction in future year rail passenger demand negatively impacts benefits and
         revenues for all phases of HS2, as there is now forecast to be less Do-Minimum
         demand available to benefit from the introduction of HS2 relative to the previous
         forecasts.

3.4.5   In addition, the reduction in benefits and revenues is greater in the Phase 2b
         Western Leg full network (i.e. Phase 1, Phase 2a and Phase 2b Western Leg) than in
         Phase 2a, with a 20% and 14% reduction in benefits and revenues respectively for
         the Phase 2b Western Leg Increment. The reduction is larger for the Phase 2b
         Western Leg due to the reduction in demand between London and the North West,
         particularly Manchester, in this step. As the Phase 2b Western Leg provides faster
         journey times and increased capacity along this corridor, a reduction in demand
         between London and Manchester impacts the Phase 2b Western Leg Network
         benefits to a greater extent than those of the Phase 2a scheme.

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[1] The December 2020 DDGs use a combination of forecasts from OBR Economic and Fiscal Outlook (EFO) publications. The
November 2020 EFO is used for short run forecasts until 2025/26, and then the March 2020 EFO is used for long run forecasts from
2026/27 onwards. The DDG files were provided to HS2 Ltd by DfT prior to being published.

3.5   Step 5: TAG updates

3.5.1   In this step, the May 2019 release of the DfT TAG Databook values used in PfMv9 were replaced by the February 2021 Interim TAG Databook[2]. As with Step 4, the longer-term GDP and population forecasts have significantly reduced relative to the previous forecasts. In addition to the negative impacts on forecast rail passenger demand (described in Step 3), this step reduces scheme benefits and revenues. This is due to reductions in the assumed rate of growth of Values of Time (VoT), which drives growth in benefits over the appraisal, and in the real (i.e. inflation-adjusted) value of rail fares, which drives growth in revenues over the appraisal. As a result, each forecast passenger journey generates fewer benefits and revenues.

3.5.2   In Step 4, growth in real fares varies with changes in real GDP and population growth due to their impact on forecast rail passenger demand, but is forecast to be approximately 2% per annum from 2040 onwards. In Step 5, this reduces to approximately 1.6% per annum from 2030 onwards. For VoT growth, Step 4 assumes approximately 1.8-2.5% growth per annum from 2030 onwards, whereas in Step 5 it is 1.5% per annum from 2021 onwards.

3.5.3   This reduction in growth in VoT and real fares (driven by changes in real GDP and population growth forecasts) has a significant impact on scheme benefits and revenues throughout the 60-year appraisal period.

3.6   Step 6: Model re-calibration

3.6.1   The PLANET Long-Distance (PLD) demand model was previously calibrated in 2012/13 using National Travel Survey (NTS) data for a base year of 2010/11 at that time. Following the rebase to 2018/19 for PFMv10a, the PLD demand model was recalibrated to reflect the changes in passenger travel patterns and industry guidance that have occurred since the previous recalibration, and to ensure the demand model parameters are consistent with the base year demand matrices and costs.

3.6.2   The revised parameters in the PLD demand model are estimated from NTS data up to 2018/19 and within the model determine how passengers respond to changes in travel costs between the modelled scenarios. Passenger response can be in the form of generation of additional rail trips (e.g. increases in trip frequency) or through abstraction of trips from other modes (e.g. from the highway or air modes).

[2] February 2021 Interim Databook provided to HS2 Ltd by DfT in advance of May 2021 release, though these are consistent.

3.6.3   The new demand model parameters result in the PLD demand model being less sensitive to a change in travel costs than in the previous model release. This means that there is a lower level of demand generation and abstraction from other modes when the HS2 scheme is introduced in PFMv10a compared to PFMv9. This in turn has a negative impact on the levels of benefits and revenues generated by the scheme.

3.6.4   The primary driver of the reduction in sensitivity in the new parameters is the update to the values of time (VoT) used in the derivation of the parameters. The VoTs used to derive the new parameters are lower than those used in the previous calibration exercise, particularly for the Commute and Other journey purposes, though the Business journey purpose is also impacted. As per TAG guidance, the VoTs used for the demand model process are distinct from those used within the scheme appraisal, which are unchanged in this step.

3.6.5   The impact on benefits is negative because there are fewer new rail trips, however, the reduction is less significant than the revenue change as new trips generate a smaller proportion of total user benefits, which are predominantly driven by existing rail users. The reduction in additional generated rail demand results in a significant drop in generated rail revenues because new revenue is directly related to levels of new rail demand.

3.7   Step 7: Opening schedule

Schedule change

3.7.1   The assumed opening dates for each phase of HS2 have changed in PFMv10a relative to PFMv9 as follows:

- Phase One (six trains per hour to/from Old Oak Common): unchanged assumed opening date of December 2029;
- Euston and Phase 2a (10 trains per hour): changed from December 2031 to December 2034; and
- Phase 2b Western Leg: changed from December 2033 to December 2038.

3.7.2   This has a negative impact on benefits and revenues of the Phase 2b Western Leg Increment because the benefits of the Western Leg are now occurring further into the future, leading to these benefits being more heavily discounted. Revenues are more significantly impacted than benefits in this step due to differences in the methodologies for calculating revenue and benefits growth.

Discount base year / Appraisal year

3.7.3   Changing the discount base year from 2019/20 to 2021/22 increases benefits and revenues by around 6% due to delaying the point from which future benefits and revenues are discounted[3].

3.8   Wider Economic Impacts (WEIs) update

3.8.1   HS2 Ltd uses outputs from the PLANET Framework Model (PFM) in the DfT's 'Wider Impacts in Transport Appraisal' (WITA) software to estimate the wider economic impacts not captured in the net transport user appraisal. This considers additional investment, employment, and productivity.

3.8.2   The datasets used in WITA contain local, sectoral level data on employment, GDP per worker and earnings. These are aligned with updated OBR economic forecasts and DfT's National Trip End Model (NTEM) version 7.2 employment forecast.

3.8.3   Assumptions used by WITA to calculate WEIs have been updated to align with PFMv10a outputs. As with the benefits and revenues generated directly from the PFM economic appraisal, the updates to modelling assumptions from the TAG update, economic forecasts, and change to the assumed scheme opening dates have collectively reduced the values of WEIs.

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[3] It should be noted that in the appraisal of the value-for-money of HS2, costs are also adjusted for the new appraisal year, and thus the impact of this adjustment on the Benefit-Cost Ratio is neutral.