5.3.3. Total Estimated Fleet Requirements

The following table shows the total fleet (standard hour plus additional peak units) assumed to be required for each option.

Table 5-4 Total Estimated Fleet Requirements (No. of Sets)

	5-car 125mph EMU	7-car 125mph EMU	8-car 125mph EMU	5-car 125mph Bi-Mode	4-car 110mph EMU
Central Case	■	-	-	-	■
Option 1	-	■	-	-	■
Option 2	-	-	■	-	■
Option 3	■	-	-	-	-
Option 4	-	-	-	■	■

The estimated fleet sizes presented in the table above have been provided for business case comparison purposes only. These numbers should in no way be viewed as recommendations for the optimum fleet size on the upgraded route, which should be the subject of further detailed analysis.

6. Operating Costs

6.1. Introduction

This chapter presents the operating cost ("opex") estimates for each rolling stock option on the upgraded Midland Mainline. Operating costs were estimated for each option using the Comparator Suite developed for the East Midlands franchise competition. The model estimates costs for operating long-distance services on the MML in the baseline scenario and in each of the options to be appraised. The difference between the option costs and the baseline cost is the figure carried forward to the appraisal.

The operating cost model considered the variable elements of operating costs only, as follows:

- Network Rail infrastructure costs;
- Diesel and electricity costs;
- Capital lease costs;
- Non-capital lease costs;
- Maintenance costs; and
- Staff costs.

Within the operating cost model, the following inputs are used to drive changes in the operating costs:

- Estimated rolling stock fleet size (number of trains and number of vehicles);
- Requirement for additional staff to operate the 6th path;
- Forecast train and vehicle mileages;
- Light and heavy maintenance materials (for HSTs).

The following sections provide further details on the input costs, growth rates and other assumptions for each of the above cost areas.

6.2. Train and Vehicle Mileages

Train and vehicle mileages are required for the calculation of infrastructure costs (variable track access charge, capacity charge, electrification asset usage charge, energy costs (diesel and electric power) and maintenance costs). Annual train and vehicle mileages were calculated based on the timetable developed for business case testing and are shown for the respective rolling stock options in the table below. Note that the vehicle mileages also account for the additional mileage incurred through peak strengthening of services. Mileage associated with empty coaching stock (ECS) moves were estimated based on the high level diagramming exercise undertaken to determine fleet requirements for the new timetable.

Mileages in the base scenario were calculated based on diagramming information provided by East Midlands Trains and are presented alongside the option mileages for comparison purposes.

Table 6-1 Annual Train and Vehicle Mileages

		5-car 125mph EMU	7-car 125mph EMU	8-car 125mph EMU	5-car 125mph Bi-Mode	4-car 110mph EMU	Total
Baseline	Train mileage	-	-	-	-	-	[redacted]
	Vehicle mileage	-	-	-	-	-	[redacted]0
Central Case	Train mileage	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Vehicle mileage	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 1	Train mileage	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Vehicle mileage	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 2	Train mileage	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Vehicle mileage	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 3	Train mileage	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Vehicle mileage	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 4	Train mileage	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Vehicle mileage	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 6-1 shows that the timetable change results in the operation of approximately [redacted] additional train miles per annum compared to the base. The 7-car fixed formation option results in a lower vehicle mileage compared to the central case (due to the peak strengthening to 10-car trains), while the 8-car fixed formation option presents a higher mileage compared to the central case due to the additional car in each train. The homogeneous fleet option presents a lower mileage than the central case, in this instance the 5-car fleet can only be doubled in peak hours whilst the 4-car fleet in the central case has been lengthened to 12-cars in the peak hours.

6.3. Infrastructure Cost Inputs

Network Rail infrastructure costs are made up of the following elements:

- Capacity charges;
- Variable track access charges; and
- Electrification asset usage charges.

The cost of traction electricity consumption (electric current for traction or 'EC4T') is a further charge recovered by NR from train operators and would normally be considered as an infrastructure charge along with the above items. However, for the purpose of this report, electricity costs are considered in a separate section on energy costs alongside diesel costs for the existing East Midlands Trains long-distance fleet on the MML.

Further details on the derivation of the inputs to the operating cost model are provided in the following sections.

6.3.1. Capacity Charge Rates

Capacity Charge rates are paid by the Train Operating Company to Network Rail based on train mileage these rates are grouped by operator and by service group, differentiating the weekday and weekend rates. The capacity charge was introduced in 2002 with the view to allow Network Rail to recover additional Schedule 8 costs (beyond the baseline) associated with the increased difficulty of recovering from incidents of lateness as the network becomes more crowded. Capacity charge rates were based on the latest Network Rail CP5 charges. The rates (weekday and weekend) for each EMT long-distance service group used in the opex model are shown in the following table.

Table 6-2 Capacity Charge Rates

Service Group	Price Year	Weekday Rate (£ per train mile)	Weekend Rate (£ per train mile)
EM1500: STP - Sheffield/Leeds	2014/15	1.986	1.331
EM1520: STP – Derby/Sheffield	2014/15	1.910	1.280
EM1530: STP – Nottingham Fast	2014/15	2.238	1.499
EM1540: STP – Nottingham Slow	2014/15	2.169	1.453
EM1560: STP – Kettering/Corby	2014/15	2.159	1.447

For the option testing, services to Sheffield were allocated to service group EM1500, while services to Nottingham were assumed as being in EM1530 (Nottingham fast).

Capacity charges are in 2014/15 prices and in the model are assumed to grow in line with RPI over the appraisal period.

6.3.2. Variable Track Access Charge (VTAC) Rates

Variable Track Access Charge (VTAC) rates are paid by the Trains Operating Company to Network Rail for use of its infrastructure. The purpose of the charge is to allow Network Rail to recover its efficient operating, maintenance and renewal costs that vary with traffic (e.g. track .wear and tear. costs). Variable track access rates used in the opex model are listed in the following table. For existing rolling stock types currently in operation on the UK rail network, VTAC rates were based on the values in Network Rail's CP5 price list. For new rolling stock not yet operational on the UK rail network (125mph EMU), VTAC was based on values provided by DfT Rail Analysis. The new DMUs (Diesel Multiple Units) deployed in the Do Minimum to replace the HSTs and Meridians are assumed to have the same VTAC rates as Bi-mode EMUs.

VTAC rates are in 2014/15 prices and in the model are assumed to grow in line with RPI over the appraisal period.

Table 6-3 Variable Track Access Charge Rates

Rolling Stock	Price Year	Source	VTAC Rate (pence per vehicle mile)
Class 222 Meridian – 4 car	2014/15	NR CP5 Price List	11.60
Class 222 Meridian – 5 car	2014/15	NR CP5 Price List	11.60
Class 222 Meridian – 7 car	2014/15	NR CP5 Price List	11.60
Class 43 HST	2014/15	NR CP5 Price List	39.37
Mk3	2014/15	NR CP5 Price List	6.81
125mph EMU – 5 car	2014/15	DfT Rail Analysis	10.54
125mph EMU – 7 car	2014/15	DfT Rail Analysis	10.54
125mph EMU – 8 car	2014/15	DfT Rail Analysis	10.54
125mph EMU – Bi-mode	2014/15	DfT Rail Analysis	11.76
DMU (replacement for Meridians and HSTs)	2014/15	DfT Rail Analysis	11.76
Class 379	2014/15	NR CP5 Price List	7.07

6.3.3. Electrification Asset Usage Charge

The Electrification Asset Usage Charge (EAUC) rates are charged to the operator for the usage of the electric installations in the infrastructure, for instance, the wires. Therefore, this is only charged to electric trains and is based on vehicle mileage. Electrification asset usage charge rates applied to electric vehicles in the opex model are listed in the following table. This is based on the rate provided in NR's CP5 price list. The EAUC rate is given in 2014/15 prices and is assumed to grow in line with RPI over the appraisal period.

Table 6-4 Electrification Asset Usage Charge Rates

Rolling Stock	Price Year	Source	EAUC Rate (pence per vehicle mile)
125mph EMU – 5 car	2014/15	NR CP5 Price List	1.70
125mph EMU – 7 car	2014/15	NR CP5 Price List	1.70
125mph EMU – 8 car	2014/15	NR CP5 Price List	1.70
125mph Bi-Mode	2014/15	NR CP5 Price List	1.70
Class 379	2014/15	NR CP5 Price List	1.70

6.4. Fuel Costs

Fuel costs in the opex model are calculated by multiplying the cost of fuel by the volume of fuel consumed. The following sections set out the traction energy consumption rates and fuel costs assumed in the opex model. Note that diesel costs are required for the calculation of operating costs in the baseline scenario.

6.4.1. Diesel Consumption Rates

Fuel consumption rates for diesel traction were provided by DfT Rail Analysis. The rates applied in the opex model are shown in the table below.

Table 6-5 Diesel Consumption Rates

Rolling Stock	Unit	Source	Diesel Consumption Rate
Class 222 Meridian – 4 car	litres per vehicle mile	East Midlands Comparator Model Suite	[redacted]
Class 222 Meridian – 5 car	litres per vehicle mile	East Midlands Comparator Model Suite	[redacted]
Class 222 Meridian – 7 car	litres per vehicle mile	East Midlands Comparator Model Suite	[redacted]
Class 43 HST	litres per vehicle mile	East Midlands Comparator Model Suite	[redacted]
DMU (replacement for Meridians and HSTs)	litres per vehicle mile	East Midlands Comparator Model Suite	[redacted]

6.4.2. Diesel Fuel Prices

Diesel prices are based on the values for Gas Oil (resource cost plus duty) provided in Table A1.3.7 of the WebTAG databook (December 2015). The prices quoted in the WebTAG databook correspond to the latest DECC forecasts. Prices in the databook are quoted in calendar years, and these were subsequently converted to financial years for input into the opex model. This resulted in an initial cost of 55.16 pence per litre of fuel for 2010 (in 2010 prices, resource cost plus duty), which was then escalated using the growth profile in Table A1.3.7. All costs provided in Table A1.3.7 are in 2010 prices and these were converted to nominal prices in the opex model through application of the GDP deflator.

6.4.3. Electric Current for Traction Consumption Rates

Energy consumption rates for electric traction were provided by DfT Rail Analysis and are shown in the table below.

Table 6-6 Electric Traction Consumption Rates

Rolling Stock	Unit	Source	Electric Traction Consumption Rate
125mph EMU – 5 car	kWh per vehicle mile	DfT Rail Analysis	[redacted]
125mph EMU – 7 car	kWh per vehicle mile	DfT Rail Analysis	[redacted]
125mph EMU – 8 car	kWh per vehicle mile	DfT Rail Analysis	[redacted]
110mph Suburban EMU – 4 car	kWh per vehicle mile	DfT Rail Analysis	[redacted]

6.4.4. Electric Fuel Prices

Electricity prices are based on the values provided for rail in Table A1.3.7 of the WebTAG databook (December 2015). The prices quoted in the WebTAG databook correspond to the latest DECC forecasts. As with the diesel costs, prices in the databook are quoted in calendar years; these were converted to financial years for input into the opex model. This resulted in an initial cost for 2010 of 6.76 pence per kWh (2010 prices), which was then escalated using the growth profile in Table A1.3.7. The costs provided in Table A1.3.7 were converted to nominal values in the opex model through application of the GDP deflator.

[9] Per vehicle mile of a total set (10)

6.5. Lease Costs

Lease cost inputs are comprised of two elements: capital and non-capital lease costs. In both cases, the costs are driven by the size of the required rolling stock fleet in terms of number of vehicles. The base fleet and fleets required for the 5 options were detailed in Chapter 5.

6.5.1. Capital Lease Costs

Capital lease costs were provided by DfT Rail Analysis. The base costs and price base assumptions are shown in the following table.

Table 6-7 Capital Lease Costs

Rolling Stock	Price Year	Source	Unit	Capital Lease Cost (£)
Class 222 Meridian – 4 car	2014/15	East Midlands Comparator Model Suite	£ per veh per annum	[redacted]
Class 222 Meridian – 5 car	2014/15	East Midlands Comparator Model Suite	£ per veh per annum	[redacted]
Class 222 Meridian – 7 car	2014/15	East Midlands Comparator Model Suite	£ per veh per annum	[redacted]
Class 43 HST	2014/15	East Midlands Comparator Model Suite	£ per veh per annum	[redacted]
Mk3	2014/15	East Midlands Comparator Model Suite	£ per veh per annum	[redacted]
125mph EMU – 5 car	2016/17	DfT Rail Analysis	£ per veh per annum	[redacted]
125mph EMU – 7 car	2016/17	DfT Rail Analysis	£ per veh per annum	[redacted]
125mph EMU – 8 car	2016/17	DfT Rail Analysis	£ per veh per annum	[redacted]
125mph EMU – Bi-Mode	2016/17	DfT Rail Analysis	£ per veh per annum	[redacted]
110mph Suburban EMU – 4 car	2014/15	DfT Rail Analysis	£ per veh per annum	[redacted]
DMU (replacement for Meridians and HSTs)	2016/17	DfT Rail Analysis	£ per veh per annum	[redacted]

DfT advised that the replacement Diesel Electric Multiple Units (DEMU), i.e. replacement vehicles for the current Meridian and HST fleet, should be assumed to have the same capital lease cost as bi-mode units.

Additionally, DfT advised that a cost of [redacted] (16/17 prices) for converting the current HST fleet to meet PRM-TSI requirements from 2020 should be included in the baseline operating costs for appraisal purposes. This cost was pro-rated for those options that only maintain a proportion of the HST fleet.

An estimated cost of [redacted] in 2015/16 prices has been included to reconfigure the Standard and 1st Class composition of the current Meridian fleet (as described in Chapter 4).

6.5.1.1. Replacement Assumptions

For the appraisal, assumptions regarding the replacement of rolling stock during the appraisal period were based on the guidance in TAG Unit A5.3. This advises that new diesel multiple units (DMU) should be assumed to have a minimum lifespan of 30 years, and new electric multiple units and electric locomotives should be assumed to have a minimum lifespan of 35 years. The following assumptions were made with regards to the replacement of rolling stock in the appraisal:

- The current baseline rolling stock Meridian fleet was assumed to be replaced in 2035/36 (approximately 30 years after the introduction of the Meridian fleet) by new Diesel Multiple Units (DMUs), and a further replacement assumed to take place 30 years later in 2065/66;
- The current HST fleet is assumed to be refurbished in 2019/20 to comply with the PRM requirements set out in the EU directives. It is assumed to be replaced in 2023/24 by new Diesel Multiple Units (DMUs), with a replacement point throughout the appraisal period in 2054/55;
- New electric trains assumed to be procured in 2019/20 for Corby services were assumed to be replaced in 2054/55. A further replacement would not be required before the end of the appraisal period in 2084/85;
- New 125mph EMUs and Bi-Modes for the Sheffield and Nottingham routes are assumed to be procured prior to the completion of the full electrification package and its operation will start with the December 2023 timetable; these trains were assumed to be replaced in 2059/60.

6.5.1.2. Treatment of Future Capital Lease Costs

The treatment of future capital lease costs was undertaken in accordance with the guidance in TAG Unit A5.3.

6.5.2. Non-Capital Lease Costs

Non-capital lease costs were not used to model the rolling stock maintenance costs. The costs to maintain the rolling stock are dependent on the lease agreement – dry, soggy or wet – and are reflected in Section 6.6.

6.6. Maintenance Costs

Maintenance costs are dependent on the type of lease agreement signed by the TOC for each rolling stock. For MML business case purposes, the assumptions on maintenance are as follows:

- HSTs are maintained through a dry lease, where the TOC carries out the entire maintenance. Therefore, in appraisal terms, only maintenance costs are captured and considered variable. These costs cover light and heavy maintenance materials and have been extracted from the latest East Midlands Direct Award model;
- Class 222's maintenance follows the current TSA agreement assumptions, which set out a maintenance cost per mileage band;
- The remaining rolling stock's maintenance costs are purely mileage-based, as reflected in the table below.

In all cases, when applicable, costs were assumed to increase in line with RPI until the demand cap year (2036/37) after which they were assumed to be fixed in real terms, as per the recent guidance issued by DfT.

Table 6-8 Mileage-Based Maintenance Rates

Rolling Stock	Price Year	Source	Unit	Maintenance Rate
Class 222 Meridian – 4 car	2014/15	East Midlands Direct Award TSA	£ per vehicle mile	[redacted]
Class 222 Meridian – 5 car	2014/15	East Midlands Direct Award TSA	£ per vehicle mile	[redacted]
Class 222 Meridian – 7 car	2014/15	East Midlands Direct Award TSA	£ per vehicle mile	[redacted]
125mph EMU – 5 car	2015/16	DfT Rail Analysis	£ per vehicle mile	[redacted]
125mph EMU – 7 car	2015/16	DfT Rail Analysis	£ per vehicle mile	[redacted]
125mph EMU – 8 car	2015/16	DfT Rail Analysis	£ per vehicle mile	[redacted]
125mph EMU – Bi-Mode	2015/16	DfT Rail Analysis	£ per vehicle mile	[redacted]
DMU (replacement for Meridians and HSTs)	2015/16	DfT Rail Analysis	£ per vehicle mile	[redacted]
110mph EMU – 4 car	2015/16	DfT Rail Analysis	£ per vehicle mile	[redacted]

** The mileage-based maintenance rate indicated for Class 222 Meridians is an indication of the average per-mile rate calculated from the TSA for the fleet's mileage range.*

6.7. Staff Costs

The 6th path delivered by the scheme which facilitates an additional hourly service to Corby will require the operator to recruit additional drivers to operate this service. Indicative analysis was undertaken to estimate the total additional driver establishment required.

Based on an end-to-end journey time of approx. 1 hour, it was assumed that 1 driver can undertake 2 round trips per diagram. With 16 hours of daily operation, the number of driver diagrams required to operate this service was indicatively estimated as 8 diagrams per day. Applying an utilisation factor of 0.46 based on the ratio of driver establishment to driver diagrams for EMT's intercity services on the MML (sourced from analysis produced for the EMT Direct Award) gave a total establishment of 17 drivers.

For the central case, Corby services are assumed to run under driver only operation (DOO). The appraisal has assumed that on-board staff on Corby services in the Do Minimum would be redeployed onto Sheffield and Nottingham services to cover the requirement for extra on-board staff resulting from the additional peak strengthening in this scenario. Note that no allowance was made in the appraisal to account for the potential reduction in on-board staff in the options considering fixed formation rolling stock which could drive staff cost savings over the central case.

6.8. Operating Costs

Total operating costs (in nominal, undiscounted values) calculated for the 60 year appraisal period are shown for each of the options in the following table.

Table 6-9 Total Operating Costs (64 years, £bn, nominal undiscounted)

	Baseline	Central Case	Option 1	Option 2	Option 3	Option 4
Staff Costs	13.58	14.15	14.15	14.15	14.15	14.15
Rolling Stock Capital Lease Costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Rolling Stock Fixed Maintenance Costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Capacity Charge	2.53	2.99	2.96	2.96	2.99	2.99
VTAC	1.05	1.13	1.11	1.23	1.20	1.23
EC4T	0.00	4.38	4.26	4.72	4.24	4.38
EAUC	0.00	0.19	0.19	0.21	0.19	0.19
Diesel Costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Variable Maintenance Costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Material Costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total	**34.68**	**35.23**	**33.76**	**35.50**	**35.24**	**37.64**
Total: Option - Base		**0.55**	**-0.92**	**0.82**	**0.56**	**2.96**

The table above presents the operational cost of each rolling stock option against the baseline. It should be noted that this includes the transition from 5 paths to 6 paths and the resulting increase in mileage. Therefore the table should not be used as a direct comparison to establish the efficiency benefits of electrification. Over the appraisal period:

The table above shows that the change to electric traction presents fuel cost changes over the base scenario (i.e., including diesel costs and all the electricity-based costs). These changes in fuel costs are typically of the order of between [redacted] in savings up to an additional cost of [redacted]. Fuel cost savings are the highest for the 7-car fixed formation, bi-mode and homogeneous fleet options (between [redacted] and [redacted] cost saving), while the 8-car fixed formation option presents a significant higher fuel cost, of around [redacted]m. .

Some of the options also deliver maintenance cost savings (material, fixed and variable maintenance) over the base, with the biggest cost reductions typically delivered by the central case, the 7-car fixed formation and the homogeneous fleet options (between [redacted] and [redacted]m). However, some options are more costly to maintain than the base, as it is especially the case of the bi-mode option ([redacted] more costly than the base), which presents higher maintenance rates or the 8-car option, around [redacted] more costly, as it operates a higher mileage.

Capital lease costs are also forecast to be lower in most of the options compared to the base. The fixed formation options deliver the biggest capital lease savings (from [redacted] in the 8-car option to [redacted] in the 7-car option), while other options as the bi-mode are the most costly than the base by [redacted] due to a higher vehicle lease cost. This is not unexpected given that 125mph EMU vehicles are assumed to be considerably less expensive to lease on a per vehicle basis compared to the DMUs that would replace the Meridians and the HSTs in the base, delivering a cost saving in those options. Conversely, bi-modes are as expensive to lease as the replacement DMUs, which delivers a more costly option compared to the base.

All of the options have higher infrastructure costs than the base primarily due to the operation of the additional '6th' long-distance service. Infrastructure cost differences between the options are primarily

driven by differences in train lengths and amount up to from £60m to £190m. The options presenting the biggest costs are the bi-mode, with higher track access charges and the 8-car and the homogeneous fleet, due to higher train mileage, while the 7-car option is the relatively less costly compared to the base for the same reason as the latter.

In terms of total operating costs, Table 6-9 shows that the 7-car option delivers savings over the base through a combination of capital lease cost, fuel and maintenance cost savings. The central case, the 8-car and the homogeneous fleet options are relatively more expensive than the base, balancing out more costly infrastructure charges with savings in fuel and maintenance for instance. Finally, the bi-mode is significantly more expensive, in terms of operating cost, than the base, mainly because of the combination of a higher lease cost, maintenance cost and infrastructure charges.

7. Scheme Capital Costs

7.1. Introduction

The current capital cost estimates for the schemes assumed to comprise the programme of upgrades on the Midland Mainline, which have been used to inform the economic appraisal, are detailed in this section.

7.2. Capital Cost Assumptions

Capital cost estimates for the infrastructure upgrade were supplied by the DfT sponsor based on information received from Network Rail. Please note that these costs were not reviewed, checked or audited as part of this work.

The costs supplied by NR were supplied with an annual profile in nominal prices. Each element of the scheme included an overlay showing the GRIP stage and existing allowances for risk and contingency. Each component of the scheme has been adjusted with reference to its stage of development to produce a risk and optimism bias adjusted costs as advised in WebTAG. Additionally costs which have already been incurred have been removed, as sunk costs which represent expenditure incurred prior to the scheme appraisal and the decision to go ahead are not considered in appraisal. A summary of the scheme cost estimates are shown in Table 7-1.

Table 7-1 Scheme Capital Cost Estimates (£m, nominal prices)

Scheme	NR Assumed Contingency (%)	Original NR Cost	Risk and Contingency Removed	Sunk Costs Removed
Midland Main Line Electrification	[redacted]	[redacted]	[redacted]	[redacted]
LDHSS	[redacted]	[redacted]	[redacted]	[redacted]
Derby Remodelling	[redacted]	[redacted]	[redacted]	[redacted]
Kettering - Corby Capacity	[redacted]	[redacted]	[redacted]	[redacted]
Bedford (exclusive) - Kettering Capacity	[redacted]	[redacted]	[redacted]	[redacted]
Market Harborough PJIF	[redacted]	[redacted]	[redacted]	[redacted]
Derby North PJIF	[redacted]	[redacted]	[redacted]	[redacted]
Kettering Depot	[redacted]	[redacted]	[redacted]	[redacted]
Leicester South LSI	[redacted]	[redacted]	[redacted]	[redacted]
Total		[redacted]	[redacted]	[redacted]

This will deliver the following:

- **Midland Main Line Electrification** New 25kV OLE between Bedford and Corby, Nottingham, and Sheffield via Derby on existing and lines to be provided by the other infrastructure interventions in this programme; adjustment of the existing Fast Line OLE between London St Pancras and Bedford South Junction to raise the permissible speeds for electric traction to 125 mph.
- **Long-distance high-speed services train lengthening.** Improved infrastructure capability to enable the introduction of longer trains (up to 240m) on the MML.
- **Phase 1 (CP5):** Bedford, Wellingborough, Kettering, Corby and Market Harborough.
- **Phase 2 (CP6):** Long Eaton, Loughborough, East Midlands Parkway, Beeston, Chesterfield and Sheffield.

- **Derby area remodelling** Segregation of the services into groups for; Birmingham to Sheffield including cross country freight, Birmingham to Nottingham and London to Sheffield. This will enable reduces journey times through improving timetabling and line speed improvements.
- **Kettering to Corby capacity**. The infrastructure capability to provide 5 trains per hour in each direction and to increase the permissible line speed to 90 mph.
- **Kettering to Bedford capacity.** The infrastructure capability to provide a 6th LDHS service from London to Kettering and one additional freight train per hour (making a total of 3 freight tph).
- **Linespeed improvements** at Market Harborough, Leicester South Junction and between Derby and Sheffield.
- **Kettering Depot**. Stabling at Kettering.

8. Economic Appraisal

8.1. Introduction

This chapter presents the results of the economic appraisal for the Midland Mainline upgrade. The assessment has been undertaken using the Department for Transport's standard approach to the economic appraisal of transport infrastructure investment as set out in WebTAG with particular focus on the guidance for appraisal of rail schemes provided in TAG Unit A5.3.

The chapter covers:

- The derivation of the scheme costs, which describes the methodology for converting base costs into a present value of costs used in the economic appraisal;
- The source of the scheme benefits, providing a summary of the source of the benefits estimated for the respective rolling stock options which are included in the present value of benefits;
- The results of the appraisal, which presents summary economic statistics (PVB, PVC, NPV and BCR) for each of the rolling stock options;
- The results of a series of tests undertaken to understand the robustness of the business case to changes in a range of key assumptions, including journey times, capital costs and demand growth; and
- The results of a series of tests undertaken to provide DfT with greater understanding of the benefits delivered by different components of the upgrade package

Standard assumptions used in the appraisal are set out in Table 8-1, below.

Table 8-1 Core Appraisal Assumptions

Item	Assumption
Appraisal period	64 years (60 years from full scheme completion)
First year of appraisal	2020/21
Last year of appraisal	2083/84
Discount rate	3.5% for 30 years from current year, 3% - years 31-64
Present value year	2010

The total appraisal period is from 2020/21 to 2083/84, i.e. a 64 year appraisal period. This reflects the phased implementation of the electrification scheme and capacity/linespeed enhancements, with the revised timetable and electrification to Corby assumed to be introduced from December 2019, and full electrification assumed to be completed by December 2023; the first year of the appraisal is therefore assumed to 2020, and the final appraisal year is 2084. To simplify the assessment it was agreed with the DfT that for the purpose of this business case, electric operations to Sheffield and Nottingham on the MML should be assumed to start from the December 2019 timetable change, rather than undertaking separate appraisals of the Corby and Sheffield/Nottingham sections.

All costs and benefits were converted to the Department's standard present value year of 2010.

8.2. Derivation of Scheme Costs

The costs associated with the MML upgrade business case were discussed in detail in Chapters 6 and 7. The following sections detail how these costs were converted for use in the economic appraisal.

8.2.1. Capital Costs

The base scheme capital costs are presented in Chapter 7. The costs supplied by NR were supplied with an annual profile in outturn prices. Each element of the scheme included an overlay showing the GRIP stage and existing allowances for risk and contingency. Each component of the scheme has been adjusted with reference to its stage of development to produce a risk and optimism bias adjusted costs as advised in WebTAG. Additionally costs which have already been incurred have been removed in line with guidance; sunk costs which represent expenditure incurred prior to the scheme appraisal and the decision to go ahead are not considered in appraisal. Finally costs are converted to 2010 prices and values and are presented in a market price base. A summary of the scheme cost estimates are shown in Table 8-2. Values are presented throughout the adjustment process for inclusion in the appraisal, including risk and contingency adjustment, removal of sunk costs and application of optimism bias. The costs in the final column were taken forward into the appraisal. This shows:

- Costs as supplied by Network Rail. Nominal (Outturn) costs inclusive of sunk coast and risks
- Removal of risk and contingency from the costs supplied
- Removal of sunk costs
- Addition of optimism bias relevant to the GRIP stage of each part of the programme
- Costs discounted to 2010 prices and values and presented in market prices.

Table 8-2 Scheme Capital Costs Included in the Appraisal (£m, nominal prices, except for appraisal values which are in 2010 present values prices and discounted)

Scheme	Original NR Cost	Risk and Contingency Removed	Sunk Costs Removed	Optimism Bias Included	Appraisal (£m, 2010 prices, discount.)
Midland Main Line Electrification	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
LDHSS	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Derby Remodelling	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Kettering - Corby Capacity	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Bedford (exclusive) - Kettering Capacity	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Market Harborough PJIF	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Derby North PJIF	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Kettering Depot	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Leicester South LSI	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

8.2.2. Treatment of Operating Costs in the Economic Appraisal

The assumptions underpinning the calculation of the base operating costs are set out in Chapter 6. This section presents the operating costs included in the economic appraisal, which form part of the overall PVC for each rolling stock option, summarised in Table 8-3 below.

Table 8-3 Incremental Operating Costs Included in the Appraisal (£m, 60 years)

Rolling Stock Option	Scheme	Total Nominal Undiscounted Factor Costs	Total Discounted Factor Costs (2010 present values)	Total Discounted Opex (Market Prices)	Total Discounted Opex with OB (Market Prices & OB)
Central Case	5-car 125mph EMU / 110mph EMU	[redacted]	[redacted]	[redacted]	[redacted]
Option 1	7-car 125mph EMU/ 110mph EMU	[redacted]	[redacted]	[redacted]	[redacted]
Option 2	8-car 125mph EMU/ 110mph EMU	[redacted]	[redacted]	[redacted]	[redacted]
Option 3	5-car 125mph EMU	[redacted]	[redacted]	[redacted]	[redacted]
Option 4	Bi-Mode 125 mph / 110mph EMU	[redacted]	[redacted]	[redacted]	[redacted]

8.3. Derivation of Scheme Benefits

The primary source of benefit in the appraisal is that derived from rail users; these benefits have been estimated in accordance with the methodology described in Chapter 4. In addition, the appraisal has also estimated decongestion benefits for existing road users, and the reduction in other 'external' costs, including accidents, noise, local air quality, and greenhouse gas emissions, both of which result from mode switch from car to rail as a result of the Midland Mainline upgrade programme. These external benefits have been calculated using the methodology provided in WebTAG Unit A5.4 – Marginal External costs which is based on assumptions relating to the change in distance travelled by car drivers as a result of changes in the distance travelled by rail passengers. Additionally, carbon and air quality benefits have been appraised using the methodology provided in WebTAG Unit A3 – Environmental Impact Appraisal.

8.3.1. Indirect Tax Impacts

Indirect tax impacts have been calculated using the methodology provided for rail schemes in Appendix a of TAG Unit A5.3. There are three main sources of indirect tax effects in rail: (a) expenditure shifts from/to goods or services due to rail revenue changes, as VAT is not levied on rail fares; (b) changes in fuel taxation due to mode shift from road to rail, which is higher than the average level of indirect taxation and (c) indirect tax effect in rail diesel, which is subject to duty, as an effect of rail diesel vehicle kilometres changes. This will result in a loss of indirect tax revenues to central government and a subsequent reduction in the present value of benefits, since indirect tax revenues are treated as negative benefits in the appraisal.

In addition, the appraisal has also considered the indirect tax impacts of a change in diesel train use. This again is of particular importance to the MML business case since electrification of the route sees the replacement of the existing diesel fleet with an electric fleet, and a subsequent loss in fuel duty received by central government.

8.4. Economic Appraisal Results

Summary economic statistics for the six rolling stock options are presented in Table 8-4. Full TEE tables are provided for each option in Appendix C.

Table 8-4 Economic Summary Statistics (£m, 2010 present values)

Option	Rolling Stock	PVB	PVC	NPV	BCR
Central Case	5-car 125mph EMU / 110mph EMU	2,292	243	2,049	9.4
Option 1	7-car 125mph EMU/ 110mph EMU	2,109	293	1,816	7.2
Option 2	8-car 125mph EMU/ 110mph EMU	2,261	315	1,946	7.2
Option 3	5-car 125mph EMU	2,043	484	1,559	4.2
Option 4	Bi-Mode 125 mph / 110mph EMU	2,292	536	1,756	4.3

Department for Transport Value for Money (VfM) Guidance identifies the following categories for defining the VfM of a particular scheme[10]:

- Poor VfM if BCR is below 1.0
- Low VfM if the BCR is between 1.0 and 1.5
- Medium VfM if the BCR is between 1.5 and 2.0
- High VfM if the BCR is between 2.0 and 4.0
- Very High VfM if the BCR is greater than 4.0

Based on the results presented in Table 8-4, the electrification of the Midland Mainline represents very high value for money, under all rolling stock scenarios. The Central Case combining 5-car 125mph EMUs for the Nottingham/Sheffield services with 4-car 110mph EMUs to Corby offers the highest value for money. The 8-car fixed formation offers similar benefits with a relatively small increase in costs over the appraisal period due to increased vehicle mileage, however this option presents opportunities to reduce staffing levels, as a result of not having to strengthen vehicles, and as such is likely to deliver a similar NPV to the 5-car fleet.

Note that the variation in the PVC presented between schemes is a combination of the differing operating costs and the impact of revenue that is assumed to accrue to the Broad Transport Budget offsetting costs. The options for the homogenous fleet and bi-model present lower value for money:

- The homogenous fleet produces lower benefits and a lower revenue forecast due to the inability of the 5-car 125mph to cope with peak hour loading on the Corby services;
- Under the assumptions in the appraisal, that 125mph Bi-Modes will match SRTs achieved by 125mph EMUs this option delivers the same benefits and revenues as the central case. In this scenario the net increase in PVC is as a result of increased operational costs.

It is worth noting that whilst these two options still present very high Value for Money for the Midland Mainline Upgrade package as a whole further sensitivity tests on a staged appraisal has been undertaken to isolate the value for Money provided by electrification itself. In these instances the difference in NPV between schemes may offer a more significant impact on the BCR.

8.4.1. Disaggregation of User Benefits

Table 8-5 provides a breakdown of the Present Value of Benefits:

[10] Value for Money Assessment: Advice Note for Local Transport Decision Makers December 2013

Table 8-5 Disaggregation of Present Value of Benefits (£m, 2010 present values)

	Central Case	Option 1	Option 2	Option 3	Option 4
Noise	5	4	5	4	5
Local Air Quality	36	36	36	36	36
Greenhouse Gases	443	440	443	440	443
Journey Quality	493	378	463	315	493
Physical Activity	0	0	0	0	0
Accidents	59	53	59	51	59
Rail Economic Efficiency (Commuting)	59	58	59	46	59
Rail Economic Efficiency (Other)	115	115	115	120	115
Rail Economic Efficiency (Business)	736	723	735	736	736
Road Economic Efficiency (Commuting)	270	243	269	234	270
Road Economic Efficiency (Other)	300	270	299	260	300
Road Economic Efficiency (Business)	141	127	140	122	141
Wider Public Finances (Indirect Taxation Revenues)	-362	-339	-361	-319	-362
Present Value of Benefits	**2,292**	**2,109**	**2,261**	**2,043**	**2,292**

As can be seen from the table above:

- User benefits account for around 70% of the present value of benefits; of this 60% is derived from rail user savings with 40% coming from decongestion benefits for road. Rail user benefits are highly comparable between options due to very small differences in timetabling between options. There is slightly more variation in decongestion benefits due to crowding levels resulting in different levels of abstraction from the highway. Approximately 80% of rail user benefits are attributed to business travellers with less than 7% coming from commuting. This is a function of; the higher values of time for business travellers, and the impact of the core specification which primarily improves the timetable for the long distance flows to London at the expense of small detriments from stations with heavy commuter demand (e.g. Wellingborough and Luton).
- Journey quality benefits represent between 15% and 22% of the PVB. This is the primary source of the difference of the PVB between options resulting from differing rolling stock capacities. Journey quality benefits are primarily from crowding relief but also include rolling stock ambiance benefits; in the central case crowding benefits account for £434m of the £493 total with rolling stock ambiance accounting for the remaining £58m. Ambiance benefits rise to £73m in Option 3 with the homogenous fleet due to the retention of inter-city rolling stock on Corby services; this benefit is more than offset by increased crowding due to the inability of strengthened 5-car services to carry peak loading on the Corby services.
- Carbon and air quality benefits represent around 20% of PVB, combining rolling stock and 'external' road benefits.
- There is a negative impact on the PVB of all options as a result of losses in indirect tax. This is primarily as a result of increased expenditure on public transport which is zero-rated for VAT purposes, and a reduction in diesel use on the rail network due to the switch to electric traction which reduces Government fuel duty receipts. Reductions in road vehicle mileage also lead to lower fuel duty receipts. This negative impact of lost indirect taxation revenues offsets approximately 14% of the economic benefits from the scheme.

8.5. Sensitivity Tests: Business Case Robustness

A number of sensitivity tests have been undertaken to understand the robustness of the business case to changes in key variables, including changes to operating cost inputs and changes to demand forecasting parameters. This section presents the results of these sensitivity tests which are summarised as follows:

- Impact on the business case of sending the 6th path to Leicester to give 5 trains per hour to Leicester
- Impact of revisions to the service pattern to:
  - Maintain peak frequency and whole day north-south connectivity from Wellingborough
  - Maintain north-south connectivity from Bedford, Luton, Luton Airport and Wellingborough
- Impact of accounting for Wider Economic Impact on the business case;
- Sensitivity to applying a cap in rail demand at 10 years and 30 years, rather than at 20 years as in the core appraisal.
- Impact of low and high diesel cost forecasts;
- Sensitivity testing with interim air quality values as provided in supplementary guidance to TAG Unit A3 (February 2016)

Sensitivity tests have typically been undertaken based on the central case, which has been identified as the more likely option for the Do-Something scenario.

8.5.1. Sensitivity Test 1: 6th Path to Leicester

The purpose of this sensitivity test is to determine the value of operating the 6th path to Leicester instead of Corby as per the central case. The primary purpose is to maintain connectivity from stations south of Kettering to Leicester. The Leicester service maintains the stopping pattern of the Corby service it replaces extending journey times. Timetabling on the route is heavily constrained by the need to accommodate freight flows on the 2-track section of route between Leicester and Kettering, which results in a sub-optimal passenger timetable with fast services 'flighted' in pairs between Leicester and St Pancras and extended dwell times at Kettering for the Leicester slow service. As a result the 'slow' service to Leicester is overtaken by the following fast service.

Table 8-6 Sensitivity Test 1: Economic Summary Statistics (£m, 2010 present values)

Scenario	PVB	PVC	NPV	BCR
Central Case	2,292	243	2,049	9.4
ST1	2,233	431	1,802	5.2

The results of this sensitivity test show that operating the 6ph path to Leicester instead of Corby reduces the value for money of the proposals. This is because:

- Operating costs are increased relative to the Central Case as a result of the additional mileage incurred on a Leicester service;
- As the Leicester service is overtaken by the following service it delivers no benefits to the London market. The revenue impact of the timetable is negative as the improvements flows south of Kettering to Leicester do not offset the losses from only having one train-per hour from Corby.

8.5.2. Sensitivity Test 2: Maintaining Connectivity

The proposed core specification has two negative impacts over the current day specification:

- Additional peak calls at Kettering and Wellingborough to cater for high peak demand, particularly in the AM peak are removed from the timetable. This reduces peak hour frequency from these stations from 5tph to 3tph and 2tph respectfully.
- Moving Bedford, Luton Airport and Wellingborough stops from the current 'slow' Nottingham service to the second Corby service results in direct connectivity being lost between these stations to areas north of Kettering.

Two sensitivities were therefore carried out to assess the impact of reinstating connectivity in the timetable:

- The first test reinstated a Wellingborough stop onto the Sheffield service with four intermediate stops throughout the day.
- The second test added in an extra stop onto each of the LDHS Nottingham and Sheffield services to reinstate north-south connectivity as fully as possible.

As with other sensitivity tests around the timetable, the core timetable specification has been adjusted to determine the likely impact on journey times and to inform the business case, however this timetabling work has not been extended to ensure a compliant timetable for each test.

The results of the sensitivity tests are shown in the table below:

Table 8-7 Sensitivity Test 2: Economic Summary Statistics (£m, 2010 present values)

Scenario	PVB	PVC	NPV	BCR
Central Case	2,292	243	2,049	9.4
Wellingborough	2,260	275	1,984	8.2
Full N-S Connectivity	1,989	668	1,321	3.0

The results of the tests show that:

- Reinstating an additional Wellingborough stop on the faster of the two Sheffield services has a relatively modest negative impact, marginally reducing the scheme NPV compared to the central case.
- Reinstating one suburban stop onto each of the four Sheffield and Nottingham services materially reduces the NPV of the business case. This is because:
  - The revenue from the timetable change is reduced with the increased connectivity (and frequency to London) not offsetting the loss in demand from disbenefits to through passengers to London. With 2015/16 demand and revenue, the timetable change would result in a net increase to national rail revenues of [redacted] against [redacted] in the Central Case.
  - Reintroducing the suburban stops with heavy peak demand into London, has a significant impact on loading on the Sheffield and Nottingham services reintroducing crowding to these high revenue markets.

8.5.3. Sensitivity Test 3: Impact of Earlier / Later Rail Demand Cap

As recommended in TAG Unit A5.3: Rail Appraisal, sensitivity tests around the rail demand cap have been undertaken by applying this earlier (10 years from the base year) and later (30 years from the base year) than in the core appraisal. The results are presented in the following table.

Table 8-8 Sensitivity Test 4: Economic Summary Statistics (£m, 2010 present values)

Scenario	PVB	PVC	NPV	BCR
Central Case	2,292	243	2,049	9.4
10 years demand cap	1,773	906	868	2.0
30 years demeaned cap	2,880	-572	3,451	Fin +

The results show that the NPV increases significantly with the later demand cap and reduces significantly with an earlier cap (essentially removing 10 years of exogenous growth – applied over 50 years). However, the BCR remains at 2.0 under the more pessimistic scenario.

8.5.4. Sensitivity Test 4: Impact of High and Low Diesel Costs

A sensitivity test has been undertaken to establish how the impact of high and low outturn diesel costs would impact on rail operating costs over the appraisal period. This has replaced DECC Central Case forecasts for diesel prices with 'low' and 'high' forecasts respectivley.

Table 8-9 Sensitivity Test 5: Economic Summary Statistics (£m, 2010 present values)

Scenario	PVB	PVC	NPV	BCR
Central Case	2,292	243	2,049	9.4
DECC High	2,292	9	2,283	248.0
DECC Low	2,292	414	1,877	5.5

The sensitivity test shows that the high diesel cost forecast would reduce the PVC by £234m while the low diesel cost scenario would increase the PVC by £172m. In each instance the BCR of the full upgrade scheme remains >2.0 delivering very high value for money.

8.5.5. Sensitivity Test 6: Higher Air Quality Benefits

A sensitivity test on Air Quality benefits has been undertaken following DfT's Supplementary Guidance on Environmental Appraisal (WebTAG Unit A3). This guidance proposes a higher damage cost for NOx emissions, which is also disaggregated by geographical area and use.

In September 2015 the Department for Environment, Food & Rural Affairs (Defra) published new guidance for valuing air quality impacts on a damage cost basis. New interim values for NOx emissions are given on a damage cost basis and are disaggregated by source of origin. For transport, values are presented for a range of geography types.

The table below presents the current monetary value of NOx damage against values included in interim guidance.

Table 8-10 NOx Damage Cost (£ per tonne)

Source	Price Year	Central	Low	High
Central Case	2010	955	744	1,085
Sensitivity Test 6	2015	25,252	10,101	40,404

In agreement with the DfT this sensitivity test has assumed that NOx emissions from diesel can be taken to be in the order of 80 grams per kilometre per train (as per TAG Unit A3 Environmental Impact Assessment) with no NOx emissions from electrical rolling stock.

Where a sensitivity test has been carried out using the guidance outline in the previous section, the results should be reported in the 'Quantitative' column of the 'Air Quality' row of the Appraisal Summary Table, but should not be included in the 'Monetary £(NPV)" column. The revised values for air quality benefits increases the monetary valuation of reduced emissions by £775m. If included in the NPV of the scheme this would increase the BCR of the Central Case from 9.4 to 12.6. NOx benefits are only realised with electrification, the impact of benefits with interim values is of high significance to the business case for electrification.

8.6. Sensitivity Tests: Incremental Benefits

Sensitivity tests have also been undertaken to provide DfT with greater understanding of the benefits delivered by different components of the upgrade package. These tests are described below.

8.6.1. Sensitivity Test A: High performance DMU Fleet

This sensitivity test isolates the potential benefits of operating the core timetable specification with an all diesel fleet assuming no electrification and of the electrification itself. Two phases of staged appraisal have been considered for this purpose.

- **Key Output 1 (minus electrification).** This sensitivity test assumes that the timetable from the main business case is operated by an all-diesel fleet. The assumption is that all services are operated by Diesel Multiple Units equivalent to today's 5-car Class 222s, adding 1 minute to journey times between London and both Nottingham / Sheffield relative to operation with 125 mph EMUs. The operation of 5-car type 222s on Corby does not allow for the same level of strengthening on the Corby services as in the Central Case. Otherwise this sensitivity test assumes a fleet, vehicle miles and peak strengthening similar to the Central Case. The intention is to produce a like-for-like comparison of diesel and electrical operational to isolate the benefits of electrification, rather than to produce a realistic future assessment of a DMU fleet. The costs and benefits of this sensitivity are subject to the assumptions above. For example a fleet incapable of meeting the journey times above, for example retaining HSTs, may deliver substantially less benefits.

- **Key Output 1.** This sensitivity test assumes that the scheme is paused on completion of Key Output 1. In this scenario Corby services are operated by 4-car 110mph EMUs as in the Central Case. Nottingham and Sheffield services are assumed to be operated by a DMU fleet equivalent to today's 5-car Class 222 with peak strengthening equivalent to the central case. Again this is intended to isolate the pure benefits of electrification rather than to provide a realistic fleet for this scenario. **This test corresponds to Key Output 1.**

8.6.1.1. Rolling Stock

The following table shows the total fleet (standard hour plus additional peak units) assumed to be required for each of the two sensitivity tests of the appraisal:

Table 8-11 Incremental Appraisal: Total Estimated Fleet Requirements (No. of Sets)

	5-car Class 222	8-car DMU	5-car 125mph EMU	4-car 110mph EMU
Key Output 1 (Minus Electrification)	■	■	-	-
Key Output 1	-	-	■	■
Central Case: Full electrification	-	-	■	■

In the electrification to Corby scenario, the Class 222 fleet operating the route to Corby is replaced by a 110 mph EMU fleet to operate under the wires. For the full electrification scenario, the Diesel Multiple Units acting as replacement of the Meridians and the HST in the baseline are replaced by 125 mph Electric Multiple Units. The numbers for each fleet have been inferred from the diagramming of the new timetable.

8.6.1.2. Capital Costs

A summary of the scheme capital cost estimates for the staged appraisal are shown in Table 8-12. Costs are presented market prices at 2010 prices and values.

Table 8-12 Incremental Appraisal: Scheme Capital Cost Estimates (£m, 2010 present values)

Scheme	KO1 (Minus Electrification)	KO1	Central Case
Midland Main Line Electrification	[redacted]	[redacted]	[redacted]
LDHSS	[redacted]	[redacted]	[redacted]
Derby Remodelling	[redacted]	[redacted]	[redacted]
Kettering - Corby Capacity	[redacted]	[redacted]	[redacted]
Bedford (exclusive) - Kettering Capacity	[redacted]	[redacted]	[redacted]
Market Harborough PJIF	[redacted]	[redacted]	[redacted]
Derby North PJIF	[redacted]	[redacted]	[redacted]
Kettering Depot	[redacted]	[redacted]	[redacted]
Leicester South LSI	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]

On the advice of Network Rail the cost of electrification to Corby is assumed to account for [redacted] (in nominal terms) of the full cost of electrification. [redacted] for the adjustment of the existing OLE South of Bedford has been retained in Key Output 2. It has been assumed that all sunk costs for electrification, amounting to £[redacted] (in nominal terms) relate to electrification between Bedford and Kettering / Corby.

8.6.1.3. Operating Costs

The following table shows the operating costs for each stage, expressed in 2010 prices and discounted to 2010, as have been taken forward for the appraisal.

Table 8-13 Incremental Appraisal: Operating Costs (£m, 2010 present values)

	Base	KO1 (Minus Electrification)	KO1	Central Case
Staff Costs	1,280	1,334	1,334	1,334
Rolling Stock Capital Lease Costs	944	1,001	944	915
Rolling Stock Fixed Maintenance Costs	223	223	223	91
Capacity Charge	368	425	425	431
VTAC	155	195	180	166
EC4T	0	0	165	553
EAUC	0	0	7	24
Diesel Costs	661	847	648	105
Variable Maintenance Costs	744	1,029	953	883
Material Costs	57	34	34	34
Total	4,432	5,087	4,912	4,535
Total: Option - Base		**655**	**481**	**104**

The table above shows that:

- Overall the Central Case has operational costs almost 2% higher than in the base. This is largely due to additional vehicle miles as a result of the 6th path. The Central Case timetable runs 17% more train miles and 32% more vehicle miles, although brings associated benefits.
- Comparing the Central Case to 'Key Output 1 minus Electrification' (which runs the same timetable with 5-car 222s) delivers a more significant assessment of the operational cost savings delivered by electrification. This shows that:
  - Overall operating costs are reduced by £551m with electrification. This represents 11% of total operating costs or 16% of total rolling stock operating costs (staff costs are unaffected between options).
  - A £165m saving in electrical costs over diesel represents a reduction in fuel costs of 20%.
  - A net maintenance saving of £277m, due to lower rates on electric rolling stock, provides a 22% cost saving with electrification.
  - A 9% reduction in capital lease costs saves £86m over the appraisal period.
- The total operational saving would offset 37% of the [redacted] (PVC) for the Midland Mainline electrification.

8.6.1.4. Benefits

The following table summarises the benefits of the staged appraisal phases, as have been taken forward in the appraisal (2010 present values):

Table 8-14 Incremental Appraisal: Benefits (£m, 2010 present values)

Incremental Benefits from Base	KO1 (Minus Electrification)	KO1	Central Case
Noise	4	4	5
Local Air Quality	-6	3	36
Greenhouse Gases	-93	31	443
Journey Quality	336	413	493
Physical Activity	0	0	0
Accidents	48	52	59
Rail Economic Efficiency (Commuting)	42	43	59
Rail Economic Efficiency (Other)	93	93	115
Rail Economic Efficiency (Business)	647	647	736
Road Economic Efficiency (Commuting)	219	239	270
Road Economic Efficiency (Other)	243	266	300
Road Economic Efficiency (Business)	114	125	141
Wider Public Finances (Indirect Taxation Revenues)	-160	-224	-362
PVB	**1,486**	**1,692**	**2,292**

The table above shows that

- 65% of the scheme benefits are achieved through the delivery of the 6th path; although this is dependent on a DMU fleet with the operational performance of the current Class 222s and capable of achieving peak strengthening as in the base. This would result in greenhouse gas emissions above current day levels resulting in a negative impact relative to the baseline.

- Overall, around £800m in PVB is achieved through electrification (this is the additional benefit in the 'Central Case' beyond 'KO1 minus electrification'. Of this £800m:
  - £536m is projected to come from reduced Greenhouse Gas emissions.
  - £262m is through the improved economic efficiency of the transport system, from faster rail times and reduced highway congestion resulting from mode shift to rail;
  - £157 if from journey quality improvements, through reduced crowding and rolling stock ambiance;
  - £54m is from externalities
  - The net impact includes a loss of £203m in indirect taxation; primarily through lost fuel duty on rail diesel.

- Electrification would also result in a revenue transfer of £333m driven by differences in sectional running times and differences in rolling stock capacities and configurations further offsetting capital costs.

8.6.1.5. Appraisal Results

The table below presents the appraisal of the scheme at each stage of development. This also shown the increment between each stage and the Central Case, isolating the NPV of electrification from each stage of development.

Table 8-15 Incremental Appraisal: Appraisal Results

Scenario	PVB	PVC	NPV	BCR
KO1 (Minus Electrification)	**1,486**	**-352**	**1,838**	**Fin +**
KO1	**1,692**	**-161**	**1,853**	**Fin +**
KO2: Central Case	**2,292**	**243**	**2,049**	**9.4**
Increment: KO1 (Minus Electrification) to KO1 (Electrification to Kettering \ Corby)	206	191	15	1.1
Increment: KO1 to KO2 (Onwards electrification to Sheffield \ Nottingham)	600	404	195	1.5
KO1 (Minus Electrification) to KO2 (Full Electrification)	806	595	211	1.4

The results in the table above show that:

- Overall, as in the tests shown above, the BCR of the whole upgrade programme sits at 9.4 and represents very high value for money.
- The timetable recast with a diesel fleet is forecast to account for nearly 65% of the PVB of the full programme whilst offering an overall cost saving. The present value of costs are reduced as although operating costs are increased with a diesel fleet this is more than offset by capital cost savings from not electrifying the route.
- Electrification to Corby on top of the 6th path would deliver a BCR of 1.1. Whilst the benefits of full electrification would deliver a BCR of 1.4. This would be forecast to deliver an additional £806m in PVB against an increase of £595m in PVC.
    - The BCR for the electrification scheme is sensitive to changes in infrastructure costs or assumptions driving operating cost savings from the switch to electric traction. A reduction in PVC of £192m would result in a BCR of 2.0. This could be achieved through either a relatively modest reduction in the capex for electrification of 13%, further operating cost savings of around 35% on the £551m saving estimated to be delivered by the conversion to electric traction, or a combination of both.

Sensitivity tests specific to benefits arising from electrification have been re-examined with relation to the incremental appraisal. Specifically this has related to:

- NOx emissions. Relative to running the specimen timetable with an all diesel fleet utilising the higher interim NOx damage costs in the appraisal would result in:
    - An additional benefit of £185m (NPV) from electrification to Corby
    - An additional benefit of £720m from onwards electrification to Nottingham and Sheffield; giving a net benefit of £905m from the full electrification scheme;
    - The DfTs supplementary guidance is the result of these tests should be reported in the 'Quantitative' column of the 'Air Quality' row of the Appraisal Summary Table, but should not be included in the 'Monetary £(NPV)" column. However, if considering these values on the monetary aspect of the appraisal the incremental business case for electrification to Corby would rise from a BCR of 1.1 to 2.1. Similarly the incremental business case for the entire electrification of the Midlands Mainline would rise from 1.4 to 2.9.
- Diesel costs. Under the high diesel costs scenario, assuming no changes to electric prices, the electrification to Corby would result in additional saving of £85m (NPV) over the appraisal period

rising to £312m with full electrification. This would increase the BCR or electrification from Corby from 1.1 to 1.9 and the BCR from full electrification from 1.4 to 2.9.

Note: The incremental benefits are subjective to assumptions relating to the fleet described in the sections above. A diesel fleet incapable of meeting journey times or capacity in the tests above would not deliver full scheme benefits, and as a result would give a larger increment to the Central Case.

8.6.2. Sensitivity Test B: KO1 (2019 Timetable)

The sensitivity test above assumes the specimen timetable is operated by a fleet of DMUs with the performance capabilities of today's Class 222s, with only a slight increase in journey times over 125mph EMU diagrams. This sensitivity test examines an alternative appraisal of development to Key Output 1 by running the 2019 timetable throughout the appraisal period. This timetable:

- Utilises the existing fleet on Nottingham and Sheffield services. The Class 222 to the 2023 Central Case, with a slight increase in running times (generally no more than a minute). However, the use of HSTs on one Nottingham diagram increases running times by eight minutes. This requires 5 HSTs to cover services that could operate using just 4 Class 222s or 125mph EMUs.
- Assumes the Corby services are operated by 4-car 110mph EMUs as in the Central Case.

8.6.3. Benefits

The following table summarises the benefits of the scheme at Key Output 1 with the operation of the 2019 timetable. This is shown alongside the benefits of the scheme

- At the same level of development with a fully strengthened DMU fleet with Class 222 performance levels; and
- For the Central Case

Table 8-16 2019 Timetable, Summary of Benefits (£m, 2010 present values)

Incremental Benefits from Base	KO1 (2019 Timetable)	KO1 (Sensitivity Test A)	Central Case
Noise	3	4	5
Local Air Quality	3	3	36
Greenhouse Gases	24	31	443
Journey Quality	346	413	493
Physical Activity	0	0	0
Accidents	35	52	59
Rail Economic Efficiency (Commuting)	11	43	59
Rail Economic Efficiency (Other)	58	93	115
Rail Economic Efficiency (Business)	485	647	736
Road Economic Efficiency (Commuting)	160	239	270
Road Economic Efficiency (Other)	178	266	300
Road Economic Efficiency (Business)	84	125	141
Wider Public Finances (Indirect Taxation Revenues)	-163	-224	-362
PVB	**1,222**	**1,692**	**2,292**

The benefits delivered by the scheme at Key Output 1 would be sensitive to the performance capabilities of the DMU fleet delivered. The use of HSTs on one of the Nottingham diagrams results in user benefits 30% lower than the same specimen timetable operated entirely by Class 222s. This would also significantly reduce the revenue benefits of the scheme; the 2019 timetable would result in an increase in national rail revenues of [redacted] against [redacted], for the same specimen timetable with Class 222 sectional running times.

8.6.4. Appraisal Results

A summary of the appraisal results is presented below:

Table 8-17 Incremental Impacts of Alternative Upgrade Scenarios (Key Output 1)

Scenario	PVB	PVC	NPV	BCR
KO1 (Sensitivity Test A)	1,692	-161	1,853	Fin +
KO1 (2019 Timetable)	1,222	69	1153	17.7
KO2 (Central Case)	2,292	243	2,049	9.4
Increment: KO1(Sensitivity Test A) to KO2	**600**	**404**	**195**	**1.5**
Increment: KO1(2019 Timetable) to KO2	**1,070**	**174**	**895**	**6.1**

The table above shows that the appraisal results are highly sensitive to the rolling stock fleet assumed to be delivered. Although Key Output 1 would still offer very high value for money with the operation of the 2019 timetable, the NPV would only be two-thirds of that with a Class 222 equivalent fleet. The lower NPV is a result of the extended journey times on the HST diagrams and as a result of increased crowding over the long term. The incremental benefits of onwards electrification to Nottingham and Sheffield would be substantially higher if the resulting DMU fleet could not achieve similar journey times to the 125mph EMUs.

9. Impact of HS2 Phase 2 on MML Upgrade Programme

9.1. Overview

HS2 Phase 2 is currently expected to open in 2033, providing fast services to Sheffield, Derby and Nottingham which will abstract demand from conventional services on the MML and have a potentially detrimental impact on the investment case for the MML upgrade programme. The Department therefore requested that analysis to be undertaken to determine:

- The impact of HS2 Phase 2 on the value for money of the MML upgrade programme – taking account of the demand abstracted by HS2 services; and
- The impact an alternative released capacity service specification to that assumed in the HS Business Case for long-distance services on the MML would have on the overall business case for HS2.

The analysis was undertaken using the assumptions for HS2 contained in the current published HS2 Business Case. This assumes that Nottingham and Derby are served by HS2 via a parkway station at Toton, requiring an interchange for city centre journeys. Sheffield is assumed to be served by a new station at Meadowhall, again requiring an interchange for trips to and from Sheffield City Centre. It should be noted that the changes to the Phase 2 alignment announced in July 2016, and in particular the proposal for HS2 to now serve Sheffield city centre directly are not reflected in the analysis.

The HS2 Business Case released capacity specification for the MML currently assumes a reduced train service specification of 5tph on the MML post-opening of HS2. This effectively assumes that the additional capacity created by the enhancement programme which facilitates an LDHS frequency of 6tph to/from London St Pancras is not utilised following the introduction of HS2 Phase 2. For this analysis, an alternative released capacity specification was defined for long-distance services on the MML based on 6tph with electrification to/from London St Pancras, maximising the capacity created by the upgrade programme.

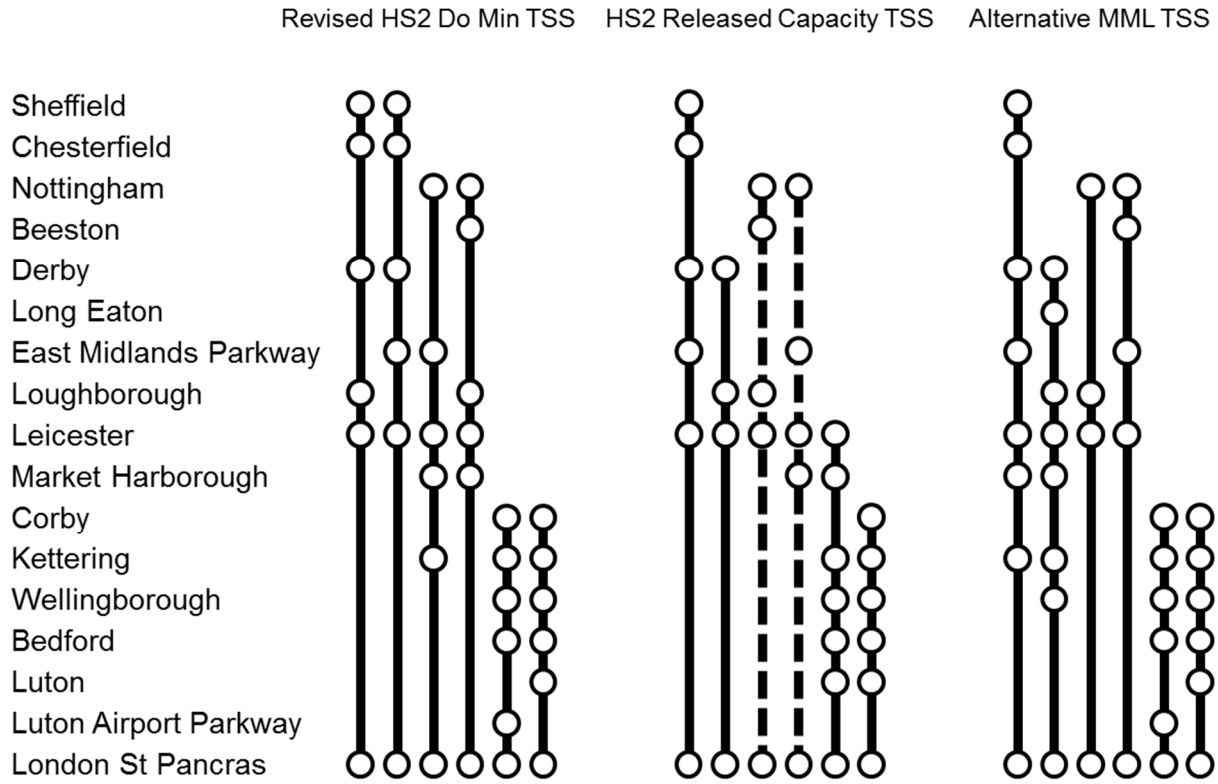
Different analytical approaches were used to determine the impacts described above. However, the first step for both involved a single run of the PLANET Framework Model (PFM) v6.1b to model the alternative 'released capacity' service specification for LDHS services on the MML. PFM is able to reliably forecast the net UK impact on demand, revenue and benefits of HS2 Phase 1, 2a and the Full Y for any particular year. The outputs from this run were then used to inform the separate impacts of an alternative MML TSS on the HS2 Business Case and the impact of HS2 on the VfM of the MML programme. Note that this run also included changes to the Do Minimum MML specification assumed in the HS2 Business Case (based on 5tph to Leicester) to reflect the timetable developed for this Business Case which assumes 4tph to Leicester and 2tph to Corby.

9.2. Analytical Approach

9.2.1. Alternative MML Released Capacity Specification

As noted above, an alternative released capacity specification for long-distance services on the MML based on 6tph to/from London St Pancras was jointly defined by DfT and Atkins, with support from HS2 Ltd and is shown in the figure below. Also presented for comparison is the released capacity TSS currently assumed in the HS2 Business Case, along with the electrification timetable developed for this Business Case, which forms the Do Minimum specification for HS2.

Figure 9-1 Alternative MML Released Capacity Specification



Note:
Solid line represents 1tph
Dashed line represents 0.5tph
Derby service in HS2 released capacity specification also includes a call at Toton (not shown)

Notable differences of the alternative released capacity TSS are:

- Compared to the 'pre-2033' MML TSS, the swapping of Market Harborough and Kettering calls from the Nottingham services into the Derby and Sheffield services facilitate further speeding-up of the Nottingham services and utilizes capacity on the Derby/Sheffield services freed up by the transfer of long-distance trips to HS2.
- Compared to the existing HS2 released capacity specification, the provision of 2tph all-day to Nottingham, facilitating twice hourly calls at Loughborough and East Midlands Parkway and hourly calls at Beeston against 1.5 and 0.5 calls in the HS2 TSS.
- Compared to both the pre-2033 and existing release capacity specifications, connectivity enhancements at Kettering (4tph all-day) and Wellingborough (3tph all-day).

Note the following additional TSS changes made to non-MML services in the alternative specification:

- Introduction of a Leicester-Toton-Derby shuttle to maintain connectivity.
- The East-West Rail service in the HS2 released capacity specification that extends north of Bedford to Nottingham via Toton was curtailed at Bedford.
- Introduction of an additional 1tph Leicester-Toton-Nottingham shuttle to maintain connectivity, with stopping pattern mirroring the curtailed EWR service north of Leicester.
- St Pancras to Bedford additional Thameslink commuter service in the Phase 2 released capacity specification was retained.

9.2.2. Appraisal Approach

The impact of the alternative MML TSS on the overall HS2 business case was appraised by running the outputs from the PFM run through the HS2 economic appraisal framework, enabling a direct comparison with the HS2 central case and calculation of the incremental benefit and revenue changes associated with the revised MML TSS. The impact of the alternative TSS on operating costs has not been assessed at this stage as Atkins do not have access to the HS2 cost models to enable a comparison to be undertaken on a like-for-like basis. Given this, the assessment of the impact of the alternative TSS is therefore limited to a comparison of the benefits and revenues with the HS2 central case.

An alternative approach was adopted for assessing the impact of HS2 on the VfM of the MML upgrade programme. For consistency with the earlier part of the appraisal (i.e. the period between 2019 and 2033) it was not appropriate or possible to use outputs from the HS2 appraisal framework for this purpose. Instead, the approach adopted was to use demand outputs from the PFM run to adjust the demand forecast in the existing appraisal. This enabled the demand abstracted by HS2 from services on the MML to be reflected in the appraisal while retaining demand (and hence benefits) for movements not affected by HS2 such as London to Leicester as well as intermediate movements along the route. It also enabled any additional benefits arising from the alternative TSS to be captured. The approach to adapting PFM demand outputs for use in the MML appraisal was based on the methodology developed by Atkins for use on the ICWC franchise, summarized as follows:

- A process known as select line analysis was used to extract from PFM the station to station demand by TOC and journey purpose, both with and without HS2.
- Select line analysis has the property of double counting trips in which passengers use two different TOCs to make their journey. The station to station demand extracted using the select line analysis was filtered to remove these double counted trips and allocate an appropriate portion across different TOCs. This was undertaken by comparing on the selected flow the number of trips for each flow in the PLD matrix to the aggregated number of trips across the given TOCs from the select line analysis. Where the difference was more than 10 trips per day, these additional trips were allocated across the respective TOCs on the basis of the distance to/from the likely interchange location. Note that the extent of double-counting on the MML was limited due to the lack of competition between operators with the majority of the long-distance market captive to EMT.

The filtered PFM station to station demand reflects the proportion of MML demand which would be retained in a post-HS2 scenario between each origin and destination station pairing. Using PFM to provide a percentage change in demand, rather than an absolute change in demand, ensures that the impact of HS2 pivots off the MML base demand and revenue used to forecast revenue prior to 2033. The table below shows the proportion of demand forecast to be retained on MML services for key London movements after the introduction of HS2 Phase 2.

Table 9-1 Proportion of Demand Retained on MML for Key London Movements

Station A	Station B	Retained Demand
London BR	Leicester	85%
London BR	Loughboro Leics	72%
London BR	East Midland Pwy	25%
London BR	Long Eaton	66%
London BR	Beeston	41%
London BR	Nottingham	42%
London BR	Derby	29%
London BR	Chesterfield	27%
London BR	Sheffield	7%

The scaling factors were then mapped to the MML appraisal process using the following methodology:

- The PFM demand uplifts/downlifts were then imported into the demand model as a timetable change in 2033 over the baseline timetable and the 2023 timetable. The resultant impact on the appraisal is to factor the incremental benefit of the timetable change to retain the uplift on the proportion of passengers who remain on the MML. For example 85% of the revenue uplift is retained at Leicester compared to only 42% at Nottingham.

- The Alternative MML TSS timetable was coded into MOIRA to obtain proxy GJTs for the revised specification. Journey time savings derived by MOIRA were factored to current values as with other option tests. Benefits by origin-destination pairing were factored, similarly to demand and revenue, to represent the proportion of demand which would still benefit in a post-HS2 scenario (i.e. 85% of passengers on Leicester and London would the forecast journey time saving, compared to only 7% of passengers between Sheffield and London.)

- Factors were used to apply scaling factors to loading by origin-destination pair within MOIRA. This effectively outputs a forecast post-HS2 loading factor for each service in the base, which were then ran through the crowding model as with other options.

Rolling stock assumptions for the alternative TSS were based on the central case for the core business case tests i.e. 110mph suburban EMUs for Corby and 5 car 125mph EMUs on the other LDHS services. Crowding levels following application of the adjustment factors were examined to Loadings were examined to determine the extent of required peak strengthening. In summary, the abstraction of long-distance demand to Derby, Sheffield and to a lesser extent Nottingham by HS2, and a rebalancing of the stopping pattern to transfer Kettering and Market Harborough demand from the Nottingham services onto the Derby/Sheffield services, reduced the amount of strengthening required for peak services, facilitating a reduction in fleet size post-2033, delivering operating cost savings compared to the central case. The size of fleet required to operate the alternative Phase 2 MML TSS is shown in the table below.

Table 9-2 Fleet Requirements for HS2 Phase 2 Alternative MML TSS (No. of Units)

	Central Case	Alternative MML TSS	Change
125mph 5 car EMU	39	31	-8

9.3. Appraisal Results

9.3.1. Impact of Alternative MML Specification on HS2 Business Case

The table below presents the impact of the revised MML Specification on the HS2 Business Case:

Table 9-3 Impact on Forecast HS2 Benefits and Revenues (£m, 2015/16 Present Values)

	HS2 Central Case	Alternative MML TSS	Change
Transport User Benefits (Business)	67,237	67,541	304
Transport User Benefits (Other)	23,220	23,445	225
Other quantifiable benefits (excluding Carbon)	414	421	7
Loss to Government of Indirect Taxes	-4,404	-4,437	-33
Net Transport Benefits (PVB)	**86,468**	**86,970**	**502**
Revenues	**46,125**	**46,407**	**282**

The table above shows that the alternative MML Specification has a marginally positive impact on the HS2 Business Case with the improving the PVB of the scheme by £502m and generating additional revenues of over £280m.

9.3.2. Impact of HS2 on Value for Money of MML Upgrade Programme

The table below shows the impact of HS2 on the benefits delivered by the MML upgrade programme:

Table 9-4 Disaggregation of Present Value of Benefits (£m, 2010 present values)

	Central Case	HS2 Test	Difference
Noise	5	2	-3
Local Air Quality	36	36	0
Greenhouse Gases	443	430	-13
Journey Quality	493	158	-334
Physical Activity	0	0	0
Accidents	59	26	-33
Rail Economic Efficiency (Commuting)	59	62	4
Rail Economic Efficiency (Other)	115	66	-50
Rail Economic Efficiency (Business)	736	364	-371
Road Economic Efficiency (Commuting)	270	116	-154
Road Economic Efficiency (Other)	300	128	-171
Road Economic Efficiency (Business)	141	60	-80
Wider Public Finances (Indirect Taxation Revenues)	-362	-244	119
Present Value of Benefits	**2,292**	**1,205**	**-1,087**

The table shows that with the introduction of HS2 the upgrade programme would only deliver 55% of the PVB of the same scheme without HS2. The upgrade programme would deliver the same benefits up to 2033 however following the introduction of HS2, the scheme would only retain:

- 33% of annual revenue benefits

- 38% of user time savings
- 24% of journey quality savings

The impact on revenue and cumulative benefits of the appraisal period is shown in the Figure below. This can be contrasted to Figure 4-6 presenting the same analysis for the central case.

Figure 9-2 Growth in Demand Over the Appraisal Period

The table below shows the impact on the BCR of the scheme:

Table 9-5 Impact of HS2 on MML Upgrade Programme: Economic Summary Statistics (£m, 2010 present values)

Scenario	PVB	PVC	NPV	BCR
Central Case	2,292	243	2,049	9.4
HS2 Test	1,205	997	209	1.2

The table above shows that the introduction of HS2 Phase 2 would have a material impact on the value-for-money of the Midland Mainline (MML) Upgrade Programme, reducing the BCR from 9.4 to 1.2. The upgrade programme can therefore be categorised as providing 'low' value for money with HS2 Phase 2.

9.4. Sensitivity Tests

To re-examine the potential benefits of operating the specimen timetable with an all diesel fleet, and the incremental benefits of electrification, the sensitivity tests in Section 8.6.1 have been assessed with the inclusion of HS2 in the baseline. In this scenario:

- Key Output 1 (minus electrification). Assumes the operation of Diesel Multiple Units equivalent to today's 5-car Class 222s (with peak strengthening as in the core HS2 scenario above);
- Key Output 1. Assumes that the scheme is paused on completion of Key Output 1. In this scenario Corby services are operated by 4-car 110mph EMUs as in the Central Case. Nottingham and Sheffield services are assumed to be operated by a DMU fleet equivalent to today's 5-car Class 222 with peak strengthening equivalent to the central case.

The results of the sensitivity tests are shown in the table below.

Table 9-6 Incremental Impacts of Alternative Upgrade Scenarios with HS2

Scenario	PVB	PVC	NPV	BCR
KO1 (Minus Electrification)	**585**	**247**	**338**	**2.4**
KO1	**767**	**430**	**337**	**1.8**
KO2: Central Case	**1,205**	**997**	**209**	**1.2**
Increment: KO1 (Minus Electrification) to KO1 (Electrification to Kettering \ Corby)	182	183	-1.0	1.0
Increment: KO1 to KO2 (Onwards electrification to Sheffield \ Nottingham)	438	566	-129	0.8
KO1 (Minus Electrification) to KO2 (Full Electrification)	620	750	-130	0.8

Examination on the impact of HS2 on the Central Case showed that the BCR of the scheme would be expected to fall from 9.4 without HS2 to 1.2 with HS2. The overall NPV reduces from £2,049m to £209m. In conjunction with Table 8-15 the table above shows that:

- The most significant impact of HS2 is on Key Output 1 prior to electrification. The NPV of the upgrade programme paused at this point would fall from £1,838m to £338m, a reduction of £1,500m. Whilst still providing a BCR of 2.4 this portion of the scheme is heavily impacted on by the inclusion of HS2. With demand loss on the introduction of HS2 a high proportion of crowding benefits, user benefits and the resulting revenue transfer, principally driven by the introduction of the 6th path and specimen timetable, are lost from the scheme.
- The incremental case for electrification to Kettering \ Corby reduces from 1.1 to 1.0, in contrast to the above this represents a change in NPV from £15m to -£1m.
- The overall incremental NPV of electrification reduces from 1.4 to 0.8, a reduction in NPV of £341m. Although this results in a BCR of <1.0 the impact on NPV is much lower than on the capacity and linespeed elements of the programme. This is because the core benefits of electrification (namely carbon savings and reductions in operational costs) are relatively unaffected by the introduction of HS2. A relatively small proportion of the benefits of electrification come from improvements to the economic efficiency of the transport system, or from a reduction in crowding. However with the inclusion of HS2 a high proportion of these benefits are lost with demand transfer away from the Midlands Mainline.

10. Summary & Conclusions

On the basis of the analysis conducted the following results are noted:

- An upgraded route could reasonably be expected to reduce journey times between London and Sheffield to 1hr 59minutes with four intermediate and 2h 04 minutes with five intermediate stops. This represents a reduction in average journey time compared to the current timings of 2hr 01mins on fast services (three intermediate stops) and 2hr 21mins on slow services (6 intermediate stops). Similarly, journey times between London and Nottingham would reduce to 1hr 34mins (currently 1hr 42mins on fast services with three stops and 1hr 51mins on slow services with 8 stops). This could lead to national rail revenue increases of up to [redacted] for flows between Nottingham and London, and [redacted] between Sheffield and London.
- Conversion to electric traction enables the impact of additional operating mileages through enhanced peak strengthening to be absorbed. Compared to the Do Minimum, the central case results in a [redacted] increase in train mileage and [redacted] increase in vehicle mileage operated, but has a broadly neutral impact on operating costs.
- With the current timetable, the existing rolling stock fleet is unable to accommodate existing demand on peak Nottingham and Sheffield services. This is particularly pronounced on the stopping service from London St Pancras to Nottingham (calling at Bedford, Luton Airport Parkway and Wellingborough). The core specification timetable reduces loading on the Nottingham and Sheffield services by removing stops south of Market Harborough which have pronounced peaks associated with commuting demand to London. Increased revenues from a combination of timetable changes and release of crowding suppression would be forecast to offset the majority of the capital investment costs over the appraisal period.

The table below summarises the key results for the options tested around the core specification timetable.

	Central Case (125mph EMU5 / 110mph EMU)	Option 1 (125mph EMU7 / 110mph EMU)	Option 2 (125mph EMU8 / 110mph EMU)	Option 3 (125mph EMU5 / 125mph EMU5	Option 4 (125mph Bi-Mode / 110mph EMU)
Revenue increase (£m PV)	1,807	1,579	1,767	1,559	1,807
Operating costs change (£m PV)	99	-79	132	92	392
Economic benefits (£m PV)	2,292	2,109	2,261	2,043	2,292
Infrastructure costs (£m PV)	1,951	1,951	1,951	1,951	1,951
Present Value Benefits (£m PV)	2,292	2,109	2,261	2,043	2,292
Present Value Costs (£m PV)	243	293	315	484	536
Net present value (£m PV)	2,049	1,816	1,946	1,559	1,756
Benefit Cost Ratio (BCR)	9.4	7.2	7.2	4.2	4.3

Sensitivity testing was undertaken to examine the benefits of individual components of the MML Upgrade Package. These considered:

- **Key Output 1 without electrification to Corby (Minus Electrification):** This delivers the capacity enhancement schemes to facilitate the 6th LDHS path and linespeed improvements. All services were assumed to be operated by 125mph DMUs with performance capabilities equivalent to Class 222s and peak strengthening as per the Central Case.
- **Key Output 1.** This test adds the electrification from Bedford to Kettering / Corby onto the scenario above. No further enhancements were assumed beyond those specified for Key Output

1. Corby services were assumed to be operated by 4-car 110mph EMUs as per the Central Case. HSTs were assumed to be replaced (from 2023/24), with Nottingham and Sheffield services assumed to be operated by a DMU fleet equivalent to today's 5-car Class 222 stock with peak strengthening equivalent to the central case.

The difference between the two tests described above is the value of electrification to Corby, while the difference between KO1 without electrification to Corby and the Central Case is the value of the full electrification scheme to Corby, Sheffield and Nottingham. These tests were undertaken to produce a like-for-like comparison of diesel and electric operation to isolate the benefits of the individual elements of the upgrade programme, rather than to produce a realistic view of a future diesel fleet. A further sensitivity was consequently undertaken to examine the impact of operating the new timetable with the existing rolling stock fleet including retention of a small number of HSTs:

- **Key Output 1 (2019 Timetable):** as above the programme is held at Key Output 1. Corby services are operated by 4-car 110mph EMUs as in the Central Case. Nottingham and Sheffield services are operated by today's fleet requiring HSTs to be operated on one Nottingham diagram, increasing journey times by approximately 8 minutes relative to the Central Case.

The results of this analysis are shown in the table below:

	KO1 (2019 Timetable)	KO1 (Minus Electrification)	KO1	Central Case	*Increment KO1(Minus Electrification) – KO1*	*Increment KO1(Minus Electrification) – Central Case*
Revenue increase (£m PV)	1,116	1,473	1,610	1,807	*137*	*333*
Operating costs change (£m PV)	213	652	477	99	*-175*	*-553*
Economic benefits (£m PV)	1,222	1,486	1,692	2,292	*206*	*806*
Infrastructure costs (£m PV)	972	470	972	1,951	*502*	*1,481*
Present Value Benefits (£m PV)	1,222	1,486	1,692	2,292	*206*	*806*
Present Value Costs (£m PV)	69	-352	-161	243	*191*	*595*
Net present value (£m PV)	1,153	1,838	1,853	2,049	*15*	*211*
Benefit Cost Ratio (BCR)	17.7	Fin +	Fin +	9.4	*1.1*	1.4

The analysis suggests:

- The economic case for the capacity works which deliver the 6th path and linespeed improvement works (KO1: Minus Electrification) is financially positive. These elements of the upgrade programme deliver over 60% of the scheme benefits for only a quarter of the overall cost. However, this does assume that the timetable is operated using a fleet wholly comprised of Class 222 or equivalent rolling stock with additional peak strengthening equivalent to that modelled in the central case.
- Given the assumptions above the incremental benefits of electrification to Corby would deliver a BCR of 1.1, whilst full electrification would deliver a BCR of 1.4 offering 'low' value-for-money.
- Running the core specification timetable with the existing fleet would substantially reduce benefits although would still offer very high value for money. In this instance the incremental benefits of electrification would be much higher, primarily due to journey time savings over the HST diagram. The results of the staged appraisal are sensitive to rolling stock assumptions as the benefits delivered by KO1 minus electrification are dependent on journey times achieved which are dependent upon fleet procurement.

Further sensitivity testing examined the impact of HS2 on the economic case of the programme. This found that the introduction of HS2 Phase 2 would have a material impact on the value-for-money of the Midland Mainline (MML) Upgrade Programme, reducing the BCR from 9.4 to 1.2. The upgrade programme can therefore be categorised as providing 'low' value for money with HS2 Phase 2. In this instance, abstraction of the long distance market to Sheffield, Derby and, to a lesser extent,

Nottingham reduces the future revenue and user benefits delivered by the 6th path. The core benefits of electrification which are reduced operating costs and carbon savings would still remain; however, the reductions in user benefits and revenues after the introduction of HS2 would reduce the incremental BCR of electrification from 1.4 to 0.8 offering 'poor' value for money.

A sensitivity test using higher damage costs for NOx emissions from DfT's Supplementary Guidance on Environmental Appraisal (WebTAG Unit A3) would increase the monetary valuation of reduced emissions dramatically by £775m. This would be of high significance to the overall business case for electrification either with or without the introduction of HS2. However, the guidance is that this value should not be included in the 'Monetary £(NPV)" column of the Appraisal Summary Table. The NPV of electrification would also be sensitive to assumptions in differences between rolling stock operating costs (for example maintenance rates) or to variations in diesel prices.

Caveats and Limitations on Analysis

It is important to note the limitations on the analysis undertaken in certain areas and where further more detailed work would need to be undertaken:

- The GTR 2018 timetable is still undergoing development. The timetables for this study were therefore developed using the current version of the GTR 2018 timetable available at the time of undertaking this work. A small number of conflicts were identified by Atkins. Some of these could be easily resolved, but others required reworking by GTR. The most serious occur in the PM peak between Up Midland Main Line services and Down Thameslink trains making crossing moves at Carlton Road and Harpenden. Resolving these would inevitably impact on GTR services through the Thameslink Core and, therefore, fell outside the scope of this work. GTR were already aware of these issues and are working on resolving them. Owing to GTR's likely timescales, the business case work was progressed with these conflicts still in the timetable. The timetabling work cannot not considered as definitive prior to the final GTR timetable.
- The estimated fleet sizes presented in this report are provided for business case comparison purposes only. These numbers should in no way be viewed as recommendations for the optimum fleet size on the upgraded route, which should be the subject of further detailed analysis.
- Currently peak strengthening on EMT LDHS services requires additional on-board staff to crew both portions of the train. For the options which consider fixed formation rolling stock the appraisal has not taken account of the potential reduction in on-board staff which these options would deliver. This would deliver staff cost savings over the central case with indicative analysis suggesting it could potentially deliver a similar NPV to the 5-car fleet.
- Revenue analysis has shown that the revenue and demand losses from reduced connectivity between stations south of Leicester and north of Leicester (including Leicester itself) resulting from the core specification are outweighed by the benefits to the major flows between London and Nottingham / Sheffield.
- Revenue transfer from crowding relief is subject to the methodological application of the PDFH approach. If longer distance journeys are subject to a lower level of constraint (for example through a high use of advance purchase with seat reservations) then this approach may overstate revenue transfer from crowding relief. This benefit is attributed to the capacity works required to provide the 6th path which offers very high value for money and would be resilient to lower capacity relief.
- The upgrade and electrification of the Midland Mainline (MML) and associated enhancement plans provide opportunities to run additional freight trains, providing the potential for benefits from removing HGV traffic from roads along the corridor. These potential benefits are not captured in the appraisal presented in this report.

Appendix A. Standard Hour Timetables

Table of assumptions and issues.

Some items were closed out during the commission and require no further action, while others require review during future stages of the Midland Main Line electrification project.

Subject	Date raised	Action	Comments
IEP SRTs and planning rules	23/05/2016	To be reviewed once validated SRTs are produced	222 SRTs, adjusted as follows based on previous RailSys analysis undertaken by Atkins. Down: -1/2 min Bedford North – Sharnbrook Jn p/p, -1/2 min Sileby Jn – Loughborough p/s, -1/2 min Loughborough – East Midlands Parkway p/s. Up: -1/2 min Ambergate Jn – Derby, -1/2 min Leicester South Jn – Wigston North Jn. Class 222 dwell times, margins and turnaround times to be used. (remit assumption)
110mph EMU SRTs	23/05/2016	To be reviewed once validated SRTs are produced	222 SRTs to be used, adjusted as follows based on previous RailSys analysis undertaken by Atkins. Down: +1/2 min St Albans – Harpenden Jn p/p, +1/2 min Flitwick Jn – Bedford S Jn p/p, no change to Up SRTs. EMU or DMU planning rules to be used, depending on the location (remit assumption)
110mph EMU planning rules	23/05/2016	Dwell times to be reviewed	EMU planning rules were used where possible. North of Bedford, DMU planning rules were used. Some concern was expressed by EMT in the workshop held on 20/07/2016 that these dwells may be insufficient, especially at Bedford.
Bedford – Kettering 4 tracking and Corby doubling	23/5/2016	None	The following signalling scheme plans were supplied by Network Rail: Bedford – Kettering 15-NE-0060 (sheet 1-4) ver 1.0 Kettering – Corby 13-NE-0075 ver B
Market Harborough linespeed improvement	23/05/2016	To be reviewed once validated SRTs are produced	-0.5 min for non-stop services (remit assumption)
Leicester upgrade	23/05/2016	To be reviewed once validated SRTs are produced	-0.5 min south of Leicester (remit assumption)