

HS2 PHASE ONE

Review of HS2-HS1 connectivity and
rail links to the Continent

November 2015

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Department
for Transport

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

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HS2/HS1 link – the options

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Introduction

HS2 is the new high speed railway proposed by the Government to connect major cities in Britain. Phase One will provide dedicated high speed rail services between London and the West Midlands. It will bring significant benefits for inter-urban rail travellers through increased capacity and improved connectivity between London, the Midlands and the North.

The Government deposited a hybrid Bill with Parliament in November 2013 to secure the powers to construct and operate Phase One of HS2 between London and the West Midlands. The hybrid Bill originally included a link to the Channel Tunnel Rail Link (HS1) in London, allowing some services to continue directly to mainland Europe via the Channel Tunnel. In March 2014, 'HS2 Plus', the first Higgins Report, concluded that the proposed link to HS1 had operational limitations and a number of adverse impacts. The Secretary of State subsequently announced his decision to remove the link from the hybrid Bill. There is no intention to include an alternative rail link in the current Phase One hybrid Bill. However, the Secretary of State believes that there is a good strategic case for links between HS2 and services to the continent, and therefore requested that HS2 Ltd work with the Department for Transport (DfT) to explore alternative options to the link which would support improved connections to the continent.

The objective of this study has been to identify the most practicable and cost-effective solution or solutions to link HS2 and HS1, while seeking to minimise adverse effects on local communities and existing transport networks.

The study has identified options which can provide better journeys to the Continent in the short to medium term, when HS2 opens. The study has also considered options to keep open opportunities to provide a direct rail connection between HS2 and HS1 in the longer term.

Baseline comparator

Each of the options considered to connect HS2 and HS1 has been compared against a baseline comparator, which is the situation if Phase One were implemented in its current proposed form (i.e. without a rail link to HS1).

As currently proposed, when Phase One opens in 2026, international passengers to or from the Midlands and the North could either walk the 750 metres (around 10 minutes' walk) between Euston and St Pancras, use the Underground (one stop), or take a bus or taxi between the stations. HS2 will improve these links by constructing a step-free route from Euston to the Circle, Metropolitan and Hammersmith & City lines at Euston Square via a new sub-surface link which forms part of the HS2 hybrid Bill scheme for Euston.

Costs quoted in this report are at 2011 prices, including allowance for risk.

Options for when HS2 opens

Enhanced walking route

Provision of an enhanced street level walking route of around 750 metres along existing roads between Euston and St Pancras is considered to represent the most likely way to transfer between HS2 and HS1 services. The enhancement could include 'greening', along with

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landscaping and other public realm improvements to provide an attractive, easy to navigate route between the two stations.

This option could be provided at a reasonable cost and without significant impacts on local communities and existing transport networks. It would also provide much greater flexibility for HS2 passengers arriving at Euston, as well as the local community and wider travelling public, enabling them to access the full range of local and international services that operate from King's Cross and St Pancras. The frequency of international services offered from St Pancras would always substantially exceed the frequency that could be offered for direct services from northern cities to the Continent.

Along with potential environmental improvements over current walking routes for those wishing to transfer between HS2 and HS1, this approach would also provide benefits for others transiting between Euston and St Pancras, and would be very likely to gain community and local authority support. Indeed, it would be worth doing without HS2. It would provide for similar journey times (around 10 minutes between stations) to the baseline comparator.

An enhanced walking route would be complemented by the underground works already included as part of HS2, which will provide step-free access between Euston and St Pancras via a sub-surface link and the Circle Line (one stop), as well as the availability of taxis.

In addition, it would lay the foundations for further potential improvements to the walking connections in the future, as part of the proposed Crossrail 2 scheme, which might offer a covered walking route, and the proposed wider renovation of Euston station.

Shuttle bus/motorised transport

It would be possible to provide a shuttle bus between Euston and St Pancras, using the existing road network, and/or an airport-style 'buggy' service for those who require assistance to transfer between the two services. The latter service might use the walking route. Since these options do not require bespoke infrastructure, they have not been considered in detail in this study, but any future design of the walking route and the development of future service specifications would be expected to take such possibilities into account.

Longer-term rail options

Development of rail options linking HS2 to HS1 began in 2009, initially focusing on options which used a section of rail tunnel combined with shared surface operation (sharing existing tracks with other services) through the Camden area. However, the operational impacts of such proposals on existing passenger and freight services on the North London Line (NLL) were concluded to be unacceptable, with Network Rail considering these options to be operationally non-viable.

Further development through to 2013 considered options which used a section of rail tunnel plus segregated surface operation (using a separate track for HS2-HS1 trains, segregated from other services) through the Camden area; this allowed provision for three trains per hour in each direction. The preferred option of this type, known as the 'NLL Enhanced Route', was presented in the November 2013 hybrid Bill. The capital expenditure required to construct the link was estimated at £610 million (2011 prices) and did not offer good value for money based on internal DfT analysis.

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As summarised in the March 2014 'HS2 Plus' report, though this proposal reduced impacts on existing services, it had significant adverse impacts on the local community during construction, offered limited possibilities for further increases to operational capacity and, based on current cost and benefit information, could not be justified in terms of value for money.

During the development of rail options, a number of fully tunnelled options were also explored, either using a rail tunnel between Old Oak Common and Camden, or a longer rail tunnel between Old Oak Common and Stratford or beyond. Fully tunnelled connections between Old Oak Common and Camden were costed at between £653 million and £854 million for a single-bore tunnel and £995 million for a twin-bore tunnel. These options had similar benefits to the segregated surface options and higher costs, and therefore did not offer good value for money either. Compared with the shared and segregated surface options, the fully tunnelled options would also substantially increase the negative impact on the local community.

The longer rail tunnel options typically provided a higher capacity (twin-track) connection from Old Oak Common to Stratford or east of Stratford. However, costs for these options were estimated to be £2,800 million to £6,000 million. As HS1 is in tunnel both west and east of Stratford, any longer tunnels would require a sub-surface connection. Whilst the benefits would be higher than the segregated surface options, the high costs imply that they would not offer good value for money.

If a rail link were provided, the frequency of direct international services to Birmingham and cities further north would be determined in part by capacity on the London – Birmingham leg of HS2. Advice from the Security and Border Agency is that domestic and international passengers could not be mixed on trains for security reasons. Immigration and customs control infrastructure and facilities would therefore be needed at any station where passengers would be able to board international services. This has implications for capacity, as international services would require additional paths on HS2. In particular, once HS2 is operating at full capacity, non-stop trains from places north of London to the Continent would reduce the number of trains serving the core market of Central London.

This constraint, along with the capacity limitations for single-track link options, would mean that only a low frequency of service would be possible from the cities served by HS2 to European destinations, especially as the limited number of train paths available for international services would need to be split to cover a broad range of train services (e.g. Manchester to Paris, Birmingham to Paris, Manchester to Brussels, Leeds to Paris).

Passive provision for rail options

Development to date has not identified a viable rail option that is capable of meeting the strategic aspirations whilst successfully addressing stakeholder concerns and value for money criteria. However, this study has also considered options to make minimum or 'passive' provision now, to leave open the option of providing a rail link if circumstances change in the future. These options would seek to ensure that there would be minimum disruption to the future operation of HS2 during construction of such a link.

Indeed, this approach has already been suggested in a number of petitions to the hybrid Bill. Two options have been previously developed: a 450m tunnel stub at Old Oak Common and a

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pair of turnout caverns in the HS2 tunnels between Old Oak Common and Euston. Construction costs for passive provision for these options are estimated at £42 million for a single tunnel stub or £103 million for a pair of turnout caverns.

More recently, HS2 Ltd has sought to develop a lower-cost solution for passive provision, providing a shorter, sprayed concrete-lined stub at Old Oak Common. The minimum direct cost of this option is estimated at around £20 million, and it introduces some additional cost and timing risks.

On the other hand, a decision to make no provision for a future rail link might offer an opportunity to remove some elements of the current design for Phase One, with a potential cost saving of £10 million-£30 million.

A key consideration with any passive provision option is how a tunnelled link would subsequently be built – how it would connect to a stub at Old Oak Common, and where and how it would connect to HS1.

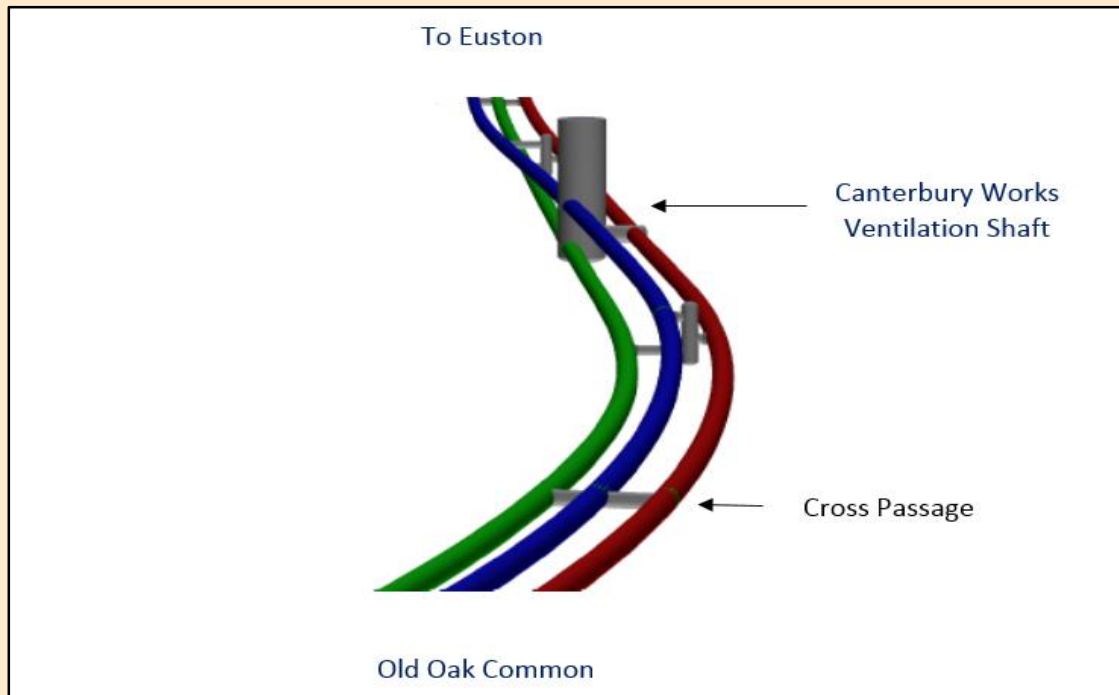
Construction of a connection to the stub

The current hybrid Bill provides for a twin-bore tunnel from Old Oak Common to Euston, with cross-passages for safety evacuation provided every 380 metres, and ventilation shafts at the Canterbury Works site (3.1km east of Old Oak Common), Alexandra Place (4.5km east of Old Oak Common) and Adelaide Road (5.9km east of Old Oak Common). Further consideration of passive provision has shown that these arrangements would have significant implications for the later construction of a tunnelled link to connect to a stub at Old Oak Common.

An entry wall or short stub provided as passive provision at the east end of Old Oak Common station box would need to be located between the two Euston running tunnels. This is so that trains could use it without causing conflicting movement across the main train flows on HS2, which would lead to significant loss of core capacity on HS2.

Physical constraints in the area immediately east of Old Oak Common would require any subsequently constructed HS1 tunnel to initially follow the previously designed alignment, between the two Euston tunnels and co-planar with them. Only after some distance could the tunnel follow a corkscrew alignment to pass under or over the northern of the two HS2 Euston running tunnels and then rise to follow alongside it to its north. For the length of this initial section, around 2.5km to 3km, the act of constructing the HS1 tunnel would sever the safety-critical evacuation cross passages between the two HS2 running tunnels. In the corkscrew section, a complex system of passageways, tunnels and alterations to the Canterbury Works vent shaft would be required to provide emergency access to the new tunnel and provide fire and smoke control to the revised arrangements. This is illustrated in Figure 1 below.

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The HS1 link tunnel (in blue) would exit the OOC box between the main HS2 Euston-bound tunnels and then pass over the green tunnel to run on the northern side of the alignment. The diagram shows the type of cross-passage that would be required either side of the ventilations shaft to cater for the height difference between the tunnels and provide a means of access/egress to the three tunnels.

Figure 1 - HS1 link tunnel corkscrew

This 2.5km-3km section would take at least two years to build. During that time, trains could not be operated on this section of HS2, as the means of emergency evacuation would have been severed and fire and smoke control disabled. Closure of HS2 for this period could only be avoided by constructing this 2.5km-3km section of the HS1 tunnel at the time of construction of HS2 Phase One. This would cost around £105 million.

Thereafter, to the east as far as Adelaide Road Vent Shaft, cross-passages would need to be broken into the existing running tunnel throughout to provide emergency evacuation for the new HS1 tunnel. Disruption from this activity could be limited by making active provision now for the eventual cross-passages (blind passages incorporating future fire doors in the southbound tunnel sides) and two eastern vent shafts designed for the eventual three tunnel arrangement. Alternatively, disruption could be fully avoided by constructing the whole of the HS1 tunnel eastwards for approximately 6km as far as Adelaide Road, in which case the simplest design would closely follow the alignment of the one formerly proposed – the HS1 tunnel staying between the two HS2 tunnels throughout, avoiding the corkscrew arrangement with its complex evacuation designs. This option would cost around £200 million.

An alternative option would be to create a cavern east of the initial corkscrew section described above to divide the HS1 tunnel into two running tunnels heading east, with their own cross-passages and vent shafts independent of HS2. However, this would be considerably more expensive, and based on original HS2 studies it is not clear where a new set of vent

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shafts could be located in the section between Queens Park and Camden, nor whether the surface ground settlement of the dividing cavern could be acceptable to affected properties above it.

Wider considerations and assessment

The options to connect with HS1 are very limited because the HS1 line is in a tunnel from just outside St Pancras to well beyond Stratford station. If the tunnel from Old Oak Common were to connect to HS1 near St Pancras in Camden, there would be substantial disbenefits in providing the connection in the future, including increased overall construction costs, issues with construction feasibility and increased environmental and community disbenefits. In particular, environmental disbenefits would be greater than if the tunnels were constructed at the same time as HS2 Phase One, as all construction access and spoil removal would need to be at the Camden portal, due to the lack of construction access at the Old Oak Common tunnel end.

The long tunnel options connecting at or west of Stratford station would be significantly more expensive, and could result in major disruption to HS1 services during the construction phase.

In light of the likely disruption to HS2, the opposition to a tunnel connection in Camden, and the high cost and additional disruption to HS1 of the longer tunnel options, it is very unlikely that a rail connection could actually be provided in the future if only passive provision were made now. Disruption to HS2 could be avoided by making more active provision now, but that would come at considerable cost, and the other issues would remain. Also, as noted above, the benefits of the link would be limited by the capacity constraints on the London to Birmingham route of HS2.

Other options

The formal petition process and the wider public debate around the HS2-HS1 link identified a number of options for improving this connection. The majority of these relate to either passive provision or rail options previously considered and addressed in previous work. The concept of a West London Line option using rail connections via South and West London was considered, but was shown to suffer operational and capacity issues with very limited journey time benefits. Feasibility work has been undertaken by Transport for London and Greengauge 21 on rail links between Stratford and Old Oak Common which suggests domestic passenger forecasts well in excess of HS2 Ltd's projections. Some of the Transport for London and Greengauge 21 assumptions are inconsistent with HS2's work, whilst other assumptions are unknown but could significantly affect the projections. These unknown assumptions include the following:

- Projections include passengers accessing Heathrow via HS2; in reality, HS2 will not directly serve Heathrow in the short or medium term.
- It is unclear whether a Crossrail station at Old Oak Common has been assumed. When HS2 and Crossrail are operational, passengers will have access to a high-frequency service between Stratford and Old Oak Common in under 25 minutes.
- It is unclear how the connection between Stratford station and Stratford International has been modelled. This connection requires a walk or interchange with DLR.

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As with the other rail link schemes, options for providing a high-capacity link would have cost, operational and environmental disbenefits, depending on the design solution adopted.

Conclusions

There is a strong case for improving the walking route between Euston and St Pancras. This would benefit local people and other travellers between the two stations, as well as HS2 passengers going to and from the Continent. HS2 passengers would have access to the full range of domestic and international services at St Pancras. The walking route might be supplemented by a shuttle bus or motorised buggy for those with luggage or restricted mobility. This could be available for the opening of HS2. It is recommended that the provision of an enhanced walking route be taken forward.

In the medium term, the provision of a Crossrail 2 station between Euston and St Pancras could offer further opportunities to enhance walking options, with a covered route.

The principle of a rail connection linking HS1 and HS2 remains strategically attractive, and HS2 Ltd remains committed to it if it could physically be achieved at a reasonable and proportionate cost. HS2 Ltd will keep an open mind to this possibility. However, the combination of tight physical constraints and the demands on existing services in this critical part of our national infrastructure make it very difficult to achieve. Longer-term opportunities for a rail connection could be safeguarded by making some provision during the construction of HS2, but lower-cost passive provision options would lead to unacceptable disruption to HS2 during construction of the link. To guard against this, the provision would have to be active rather than passive, and this would come at considerable cost. There are a number of other reasons why future investment in the rail link would be highly unlikely – notably because of the other difficulties with later construction, and the limited capacity that would be available for international services on HS2. Accordingly, neither active nor passive provision for a rail link is recommended.

High Speed Two Limited

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1 Non-technical summary

1.1 Context

- 1.1.1 In November 2013, the Government deposited a hybrid Bill with Parliament to secure the powers to construct and maintain Phase One of HS2 between London and the West Midlands. The hybrid Bill included provision of a link between Old Oak Common station and the High Speed One link (the HS2-HS1 link) to the north of St Pancras station which would link the two high speed railways and facilitate direct high speed services from across Britain to mainland European destinations via the Channel Tunnel without stopping at St. Pancras International or Euston stations. Old Oak Common would provide the stop in London for these international services.
- 1.1.2 The development of rail options for the HS2-HS1 link began in 2009; these comprised a rail tunnel plus shared surface operation. In January 2012 the Post-Consultation Route (PCR) option was announced. The PCR option ran in tunnel between Old Oak Common and a portal north-west of Primrose Hill, and then through Camden, sharing tracks with the North London Line (NLL). However, HS2 Ltd's Sponsor's requirement of three trains per hour (3tph) could not be achieved without significant implications for passenger and freight services on the NLL. For these reasons, Network Rail considered the rail tunnel plus shared surface operation options to be operationally non-viable. Instead, the scheme was further developed into rail tunnel plus segregated surface operation options, providing a separate track from the NLL for HS2-HS1 trains (segregated running). This culminated in the 'NLL Enhanced Route', which was the scheme taken forward into the hybrid Bill.
- 1.1.3 The first Higgins Report, HS2 Plus, March 2014 concluded that the hybrid Bill HS2-HS1 option was the most cost-effective solution to delivering three trains per hour, but noted that the proposal had operational limitations and also had adverse impacts on the West Coast Main Line (WCML), on freight capacity, on future commuter growth on the NLL, and on the community of Camden. Removing the HS2-HS1 link was estimated to reduce the forecast cost for Phase One by £700 million (including risk provision). The HS2 Plus report concluded that it would be better to consider alternatives that could deliver the benefits of the link without compromising existing services. On 17 March 2014, in response to HS2 Plus, the Secretary of State announced his decision to remove the link from the hybrid Bill.
- 1.1.4 The Secretary of State continues to believe that there is a good strategic case for links to the continent and has asked HS2 Ltd to work with the Department for Transport (DfT) to explore alternative options that would improve connections to the continent. The objective of this review is to consolidate existing information on options for connecting HS2 to HS1.
- 1.1.5 It comprises:
1. A review of rail options previously proposed to connect HS2 to the existing High Speed 1 rail network, including how these options could be delivered at a later date through passive provision;

2. An assessment of options previously proposed to link Euston and St Pancras stations, including technologies such as Automated People Mover (APM) or travelator systems; and
3. A high-level review of any options not considered above that would help improve wider connectivity to the continent, including petition items and enhanced street level walking routes between Euston and St. Pancras stations.

1.2 Option families

1.2.1 An initial review indicated over 30 separate options. Similar options were grouped into 'option families' as set out in Table 1: HS2–HS1 option families.

Table 1: HS2–HS1 option families

Option family	Family sub-group
Baseline comparator	Walk between Euston and St Pancras
	LU/Bus/Taxi between Euston and St Pancras
	Crossrail 1 between Old Oak Common and Stratford
Enhanced walk options at Euston	Enhanced street-level walking route
	Use of Crossrail 2 station as walking route
Rail Options Central	Rail tunnel plus shared surface operation
	Rail tunnel plus segregated surface operation
	Rail tunnel between Old Oak Common and Camden
Rail Options Eastern	Longer-distance rail tunnel between Old Oak Common and Stratford or beyond
Rail Options Alternative	West London Line option ¹
	Greengauge 21
	Euston Cross ¹
	Kings Cross HS2 terminal ¹
Automated People Mover (APM) and travelator systems	Elevated APM
	Sub-surface APM
	Elevated travelator or elevated walkway

1.3 Baseline comparator

1.3.1 In order to appraise the wide range of link options, they have been compared with the situation reflecting the Secretary of State's decision to remove the link from the hybrid Bill.

¹ Raised as petition items.

HS2 Phase One, with no HS2-HS1 link, is referred to as the 'baseline comparator'. It reflects how international travellers might transfer between HS2 and HS1 services in the future with the hybrid Bill scheme and other committed infrastructure. Interchange between HS2 and HS1 services in the baseline could be by:

- walking between Euston and St Pancras via Euston Road, Phoenix Road or Polygon Road;²
- getting the bus between Euston and St Pancras;
- taking the Underground (Victoria or Northern Line) between Euston and St Pancras;³
- using taxi services between Euston and St Pancras; or
- using the hybrid Bill sub-surface walk link between Euston and Euston Square stations, which would provide a step-free route to the Circle, Metropolitan and Hammersmith & City Lines.

1.3.2 Within the baseline scenario, an alternative to travelling into Euston would be for international passengers to use Crossrail 1 between Old Oak Common and Stratford.⁴ They would change onto Crossrail 1 services at Old Oak Common, from where Stratford is a 24-minute journey. Passengers would then need to use the DLR to reach Stratford International Station. As Stratford International currently has no immigration and customs controls facilities for international travel, these facilities would need to be introduced to accommodate international travel, or international travellers would need to travel on HS1 domestic services to Ebbsfleet before transferring onto international services.

1.4 Appraisal framework

1.4.1 Whilst some of the rail-based options have undergone a relatively thorough analysis with a degree of certainty attached to both cost and benefits, the alternative rail options, APM, elevated travelator/walkway options and enhanced walk options are much less developed. In setting up an appraisal framework to review this broad set of options, it has been necessary to adopt a consistent set of assessment criteria. Therefore, an appraisal process was adopted based on that set out in the document HS2 - Route Development Appraisal Template, HS2 Ltd, July 2013.

1.4.2 Figures on passenger demand for rail and non-rail services. have been taken from the work previously undertaken by HS2 Ltd. Table 2 splits potential demand into international rail demand to and from the continent; domestic demand, where services are available for inter-regional and regional domestic travel; and local demand, corresponding to local demand for an option available to the general public. Potential demand is expressed as passengers over

² Euston and St Pancras stations are 750 metres apart via the shortest street-level walking routes.

³ Euston and St Pancras stations are one stop apart on the Northern and Victoria lines.

⁴ Crossrail 1 station would be provided at Old Oak Common as part of the HS2 proposal.

the morning three-hour peak period (0700-1000) for rail options, APM/travelator/walkway options and enhanced walk options.

Table 2: High level demand estimates at HS2 Phase Two opening

Option family	Potential passenger demand 0700-1000			
	International demand	Domestic demand	Local demand	Total demand
Enhanced walk options at Euston	250-800	N/A	2,000	2,250-2,800
Rail tunnel plus shared surface operation	1,300	0	NA	1,300
Rail tunnel plus segregated surface operation plus all rail tunnel options	1,300	0-1,500	NA	1,300-2,800
APM, elevated travelator/walkway options	250-800	NA	2,000-3,000	2,250-3,800

1.5 Enhanced walk options at Euston

1.5.1 When Phase One of HS2 opens in 2026, international passengers arriving at Euston station will be able to walk to St Pancras station where international services depart. Enhanced walk options between Euston and St Pancras have not been developed previously and could comprise:

- enhanced street level walking route; and
- use of Crossrail 2 station as walking route.

Enhanced street level walking route

1.5.2 One idea is to use existing streets to provide enhanced street-level walk connections between Euston and St Pancras stations. This could provide an attractive route, given appropriate urban realm treatment including landscaping, 'greening' and signage. These routes would avoid Euston Road (shown in blue on Figure 1: Enhanced walk routes) and instead run along Phoenix Road (shown in red). The costs of providing this option should not be underestimated (previous estimates have included £2.5 million, excluding risk and optimism bias), but it would be significantly cheaper than other options.

1.5.3 This option was included as part of the London 2012 Olympic Transport Strategy for passengers arriving at Euston station and connecting with Javelin services to the Olympic Park from St Pancras. Whilst there are few data available on how many Games spectators used this route, anecdotal evidence indicates usage was relatively low. However, London Borough of Camden has indicated that it would be in favour of options that encourage walking between Euston and St Pancras, as long as such options were designed to a high standard. Any scheme would need to be developed in association with London Borough of Camden, but it is likely to be a favourable option to them and to local resident associations.

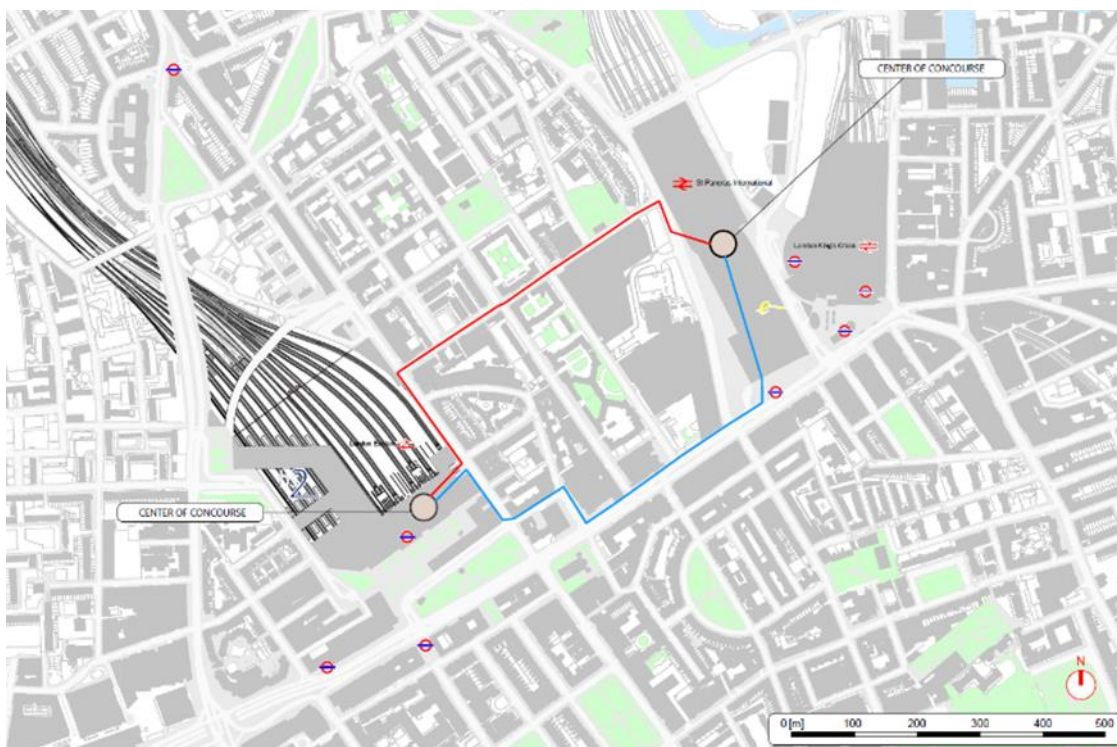


Figure 1: Enhanced walk routes

1.5.4 The Generalised Journey Time (GJT) for enhanced walk options is similar to the baseline comparator but is around 67 minutes longer than the rail options when measured between Old Oak Common and Stratford International stations.

1.5.5 No formal costing of these options has taken place, but costs are relatively low. There are potential environmental benefits, and possible community and local authority support, but journey times are similar to the baseline comparator.

Use of Crossrail 2 station as walking route

1.5.6 A new Euston/St Pancras station would be provided as part of the Crossrail 2 proposals, with station entrances connecting to St Pancras and Euston. This station connection potentially forms an additional walking route between the two stations. However, the preliminary completion date for Crossrail 2 is early in the 2030s, so any options associated with Crossrail 2 would not be in place for the opening of Phase One of HS2 in 2026.

1.5.7 The walking distance on this route would be comparable with existing street-level routes but would involve a number of level changes and entry/exit to the 'paid' area. However, user benefits could include its being weather-protected and the fact that it would feature a high level of mechanical assistance through escalators and travelators.

1.5.8 The Crossrail 2 proposals have not been developed to facilitate through-movements of this type. Discussions with TfL about interchange between Euston and St Pancras indicate that the preference would be for any between-station movements of this type to be managed

outside the station. TfL and HS2 Ltd would need to work closely together to further explore this option.

1.6 Rail options

1.6.1 Given the large number of rail link options proposed to connect HS2 with HS1, these were grouped into broad 'families' to facilitate a manageable comparison of options. The families are set out in Table 1: HS2–HS1 option families and are reviewed in the following sections:

- Rail Options Central - Rail tunnel between Old Oak Common and Camden, including options that share tracks with the NLL (the PCR options), options that propose segregated running along the NLL (the NLL enhanced options), and tunnelled options.
- Rail Options Eastern - Longer-distance rail tunnel between Old Oak Common and Stratford or beyond.

1.6.2 The construction costs, morning peak period passengers, benefits, operating and rolling stock costs (excluding construction costs) are summarised in Table 3: Costs and benefits – rail options. The cost for routes via Camden would be between £580 million and £995 million and would give a saving in GJT over the baseline of around 70 minutes.⁵ GJT savings are similar for all options owing to similarities in the route alignments.

1.6.3 Whilst the Present Value of Benefits (PVB) is greater than the Present Value of Costs (PVC), the PVC does not include the cost of construction and including this would greatly reduce the difference.

⁵ GJT has been estimated for each option and compared to the baseline comparator. See in Appendix D.

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Table 3: Costs and benefits – rail options⁶

Family	Option description	Construction cost £m 2011 prices undiscounted to a present value ^{7 8}	Patronage AM peak	Present Value of Benefits (PVB) and revenue £m ⁹	Present Value of Costs (PVC) includes operating and rolling stock £m ¹⁰	PVB minus PVC	Passive provision cost £m ¹¹
Rail Options Central	Rail tunnel plus shared surface operation	£580 to £890 (3 options)	1,300	£2,515	£1,837	£677	£42
	Rail tunnel plus segregated surface operation	£610 to £630 (5 options)	2,800	£4,110	£3,182	£928	£42
	Rail tunnel between Old Oak Common and Camden	£653 to £854 (single bore tunnel) £995 (twin bore tunnel) (6 options)	2,800	£4,110	£3,182	£928	£42 ¹²
Rail Options Eastern	Longer distance rail tunnel between Old Oak Common and Stratford or beyond	£2,785 to £6,000 (3 options)	>2,800	>£4,110	>£3,182	unknown	£103

⁶ Journey time benefits are assumed to be similar at around 70 GJT minutes for all scenarios, based on passengers boarding at Old Oak Common.

⁷ Construction costs from previous HS2 estimates for multiple infrastructure options and summarised, with sources, in Appendix C.

⁸ Cost estimates exclude property purchase and potential compensation costs but include contingency and optimism bias.

⁹ PVB from *HS1/HS2 link economic appraisal update V3 05*, March 2015.

¹⁰ PVC from *HS1/HS2 link economic appraisal update V3 05*, March 2015.

¹¹ Passive provision described later in this section.

¹² One option in this family (R6) has a passive provision cost of £103 million.

1.6.4 The broad alignment of each route is shown in Figure 2: HS2-HS1 rail options.

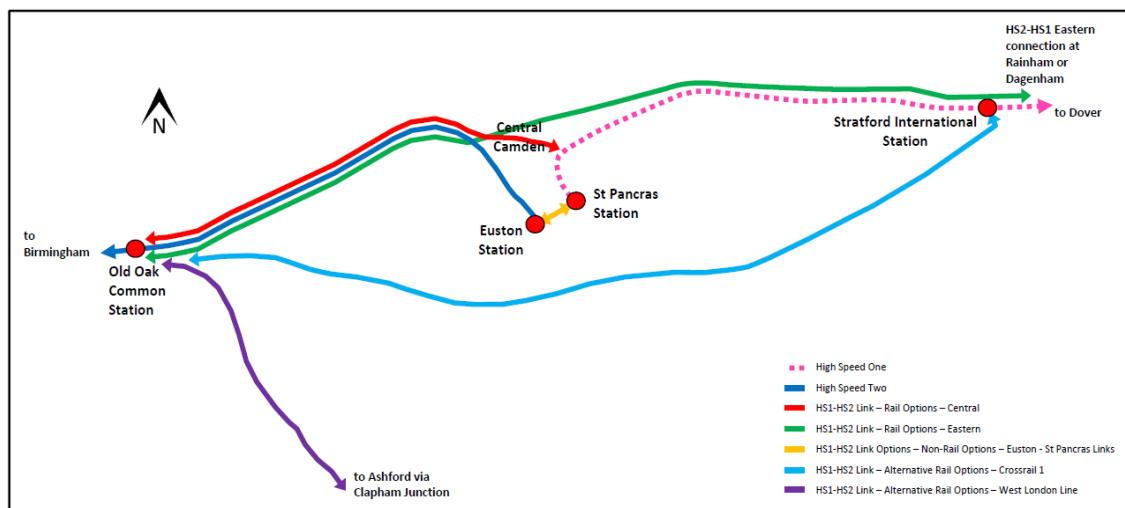


Figure 2: HS2-HS1 rail options

Rail Options Central

Rail tunnel plus shared surface operation and rail tunnel plus segregated surface operation

- 1.6.5 These options run from Old Oak Common Station to the Camden area using a single bore tunnel, before joining the NLL, using this corridor either as a shared or segregated route to connect to the HS1 link north of St Pancras.
- 1.6.6 Timetable capacity evaluation work by Network Rail (NR) in July 2012 concluded that shared use of the NLL would not meet the Sponsor's requirement of three high speed services per hour, in each direction, without a significant reduction in TfL's and NR's passenger and freight services in and around the NLL. These options would require the widening and/or replacement of some of the existing viaducts and bridges along the NLL corridor, with consequential track possessions and speed restrictions. They would also require the severance of roads, resulting in traffic diversion and property demolition. Shared options would not meet the Sponsor's requirement (3tph) and would limit international rail services to six trains per day, resulting in a morning peak period patronage forecast of around 1,300 passengers (one-way), with the option family having a PVB of £2,515 million and a PVC - excluding construction costs - of £1,837 million (a difference of £678 million). Cost estimates for these options range from £580 million to £890 million at 2011 prices, inclusive of all construction costs, indirect costs (design and project management), efficiencies and risk allowances. Cost estimates exclude property purchase and potential compensation costs, which could be significant.
- 1.6.7 Due to the impact on NLL services, these options were rejected in favour of options using tracks segregated from NLL operations - for instance, the NLL Enhanced option which was initially developed and proposed by NR and later presented as the HS2-HS1 link proposed scheme in the HS2 London - West Midlands Environmental Statement, November 2013. These options could be achieved without permanently reducing the existing rail operation

capacity of the NLL and would be capable of meeting the Sponsor's requirement of three trains per hour. This would allow these options to accommodate international services at six trains per day (6tpd) alongside domestic services at two trains per hour (2tph). Adding to projected international demand of 1,300 peak period passengers, domestic services could attract additional patronage. HS2 Ltd estimates that domestic demand could be in the region of 1,500 passengers in the morning peak period, resulting in total morning peak patronage of 2,800. In contrast, both TfL and Greengauge 21 have developed demand forecasts which are considerably higher than those of HS2 Ltd, although the number of trains per hour required to deliver these forecasts is unclear.

- 1.6.8 As set out in Table 3, the segregated surface options would have a PVB of £4,110 million and a PVC of £3,182 million, excluding construction costs. This gives a difference of £927 million. The difference between PVB and PVC is higher than the £677 million for the shared options, as a result of the additional user benefits arising from domestic passengers. Costs for these options range from £610 million to £630 million (2011 prices) inclusive of all construction costs, indirect costs (design and project management), efficiencies and risk allowances. Cost estimates exclude property purchase and potential compensation costs, which could be significant. One of the shared options (at £890 million) has a higher cost than the segregated options because the shared route is much longer and requires more infrastructure widening works.
- 1.6.9 However, the segregated options would cause substantial disruption to rail services during construction as a consequence of the need for NLL track upgrading. Whilst the impacts on the local community, both temporary and permanent, would be similar to the shared options, there would be a requirement for additional land take under some of the segregated options.
- 1.6.10 The March 2014 Higgins Report HS2 Plus concluded that although the hybrid Bill HS2-HS1 (segregated) link proposal was the most cost-effective solution to delivering three trains per hour, the proposals had:
- operational limitations;
 - adverse impacts on the West Coast Main Line (WCML);
 - adverse impacts on freight capacity;
 - adverse impacts on future commuter growth on the NLL; and
 - adverse impacts on the community of Camden.
- 1.6.11 The hybrid Bill link option was subsequently removed from the scheme by the Secretary of State. All surface shared and segregated options can therefore be considered to have been previously rejected.

Rail tunnel between Old Oak Common and Camden

- 1.6.12 The group of options based on a rail tunnel between Old Oak Common and Camden would use segregated tunnels. These would remove the conflict with NLL operations, as well as providing opportunities for use by additional domestic services.
- 1.6.13 The options would involve a variety of single bore and twin bore alignments and could start at either Old Oak Common or from a pair of underground turnout caverns on the HS2 main lines between Old Oak Common and Euston.
- 1.6.14 The capacity provided by these options would provide a positive benefit for existing and future rail operations but there would be considerable impacts on rail operations during construction, with the tunnel portal ramp emerging in the Camden area. This would result in prolonged track possessions and service disruption to the NLL, Midland Main Line and even to HS1.
- 1.6.15 The land take required for the tunnel portal and the need for extensive works to existing rail structures would lead to impacts to local community and businesses - particularly during construction - including demolition of residential and commercial properties, and permanent road closures. These would represent a substantial increase in the negative impact on local communities, in comparison with the shared and segregated rail link options.
- 1.6.16 Cost estimates (2011) for tunnel options range from £653 million to £854 million for a single bore tunnel and £995 million for a twin bore tunnel. Costs for all options were calculated at 2011 prices and are inclusive of all construction costs, indirect costs, efficiencies and risk allowances. Cost estimates exclude property purchase and potential compensation costs.
- 1.6.17 These options based on a rail tunnel between Old Oak Common and Camden would provide a direct link between HS2 and HS1 and would be able to exceed the original Sponsor's requirement of three trains per hour. A twin bore tunnel would enable higher service frequencies to be run, potentially generating greater benefits than segregated options. Morning peak period patronage for the single bore tunnel has been estimated at around 2,800 passengers, one-way, with the services having the same PVB (£4,110 million) and PVC (£3,182 million, excluding construction costs) as the segregated options.
- 1.6.18 Tunnels are complex engineering works and require comprehensive support studies. As these options have only been developed to concept design stage, there is limited information available on which to gauge the full extent of potential risks, most of which relate to unknown geotechnical conditions, and underground structures and services. Risks might include tunnelling at shallow depths, associated risks of settlement, extensive ground treatments, and widening and refurbishment of existing rail structures.

Rail Options Eastern

- 1.6.19 These options would use segregated, long-distance tunnels (high speed single track or conventional speed twin track) between Old Oak Common and either Rainham or Dagenham in Essex. These would remove the conflict with NLL operations and avoid adverse impacts on rail operations in the Camden area during construction.

- 1.6.20 Limited information is available on the service capability of a single track option. The twin track options would offer service capacity above HS2 Ltd's Sponsor's three trains per hour requirement and would provide opportunities for further increase in service provision. However, earlier work highlighted significant construction challenges in connecting to HS1 before or at Stratford International. This would be resolved by joining the HS1 route to the east of Stratford, although the lack of interchange at Stratford would be expected to significantly reduce benefits associated with domestic services.
- 1.6.21 The impact of these options on local communities could be substantially lower than other rail options, as the works would be more limited and would occur in a less populated area. It should be stressed that there is no environmental impact study available for these rail link options.
- 1.6.22 Cost estimates for these longer-distance tunnelled options are the highest of all under consideration and range from £2,785 million to £3,420 million for a conventional speed connection, with the option for a link capable of high-speed operation estimated at £5,500 million to £6,000 million. Costs for all options were calculated at 2011 prices and are inclusive of all construction costs, indirect costs, efficiencies and risk allowances. Cost estimates exclude property purchase and potential compensation costs.
- 1.6.23 Morning three-hour peak period patronage has been estimated at around 2,800 passengers, one-way. The longer-distance 'rail tunnel between Old Oak Common and Stratford or beyond' options would have a GJT similar to the options running through Camden.

Passive provision

- 1.6.24 Passive provision is defined as the minimum amount of works required to enable the future construction of a rail link with acceptable levels of impact on existing services, infrastructure and environment. It is feasible to support the possibility of constructing any of the rail options described above - but with construction at a later date - by including adequate passive provision. This would make it easier to incorporate a rail link in the future without unacceptable disruption to HS2 and other rail services. This approach has already been suggested in a number of petitions to the hybrid Bill.
- 1.6.25 The existing HS2 Ltd demand forecast predicts that future passenger numbers would provide marginal value for money from the link designed in the hybrid Bill. But by observing actual passenger numbers on HS2, ongoing demand trends for Eurostar and the relevant air markets over the coming years, a more robust forecast of future demand for a link from HS2 to HS1 could be developed. However, the cost of passive provision is not insignificant, and a judgement call would be required on whether the possibility of a stronger future case for the link would be worth the additional cost now.
- 1.6.26 In the future, there could be a major change in costs of travel (or other factors), and again this could improve the case for a direct rail link between HS1 and HS2. A combination of increased economic activity in the Midlands or North, increased road travel costs, increased rail congestion in central London, and changes to border and security controls could result in an

increase in demand, to the point where a rail-based option becomes viable. Without passive provision, levels of disruption, particularly resulting from construction, to (future) existing rail services, impacts to local community and business as well as increased costs, at a later stage, could be considered unacceptable.

1.6.27 In order to allow for any of the rail options to be deferred to a later date, passive provision could comprise:

- For the Rail Tunnel Plus Shared, Rail Tunnel Plus Segregated, and Rail Tunnel Central families of options, constructing a 450m tunnel stub from Old Oak Common Station would permit the option to be delivered at a later date, eliminate the need for future changes to operational layouts, and minimise disruption to high speed rail services. Constructing the tunnel stub from Old Oak Common is estimated to cost approximately £42 million (at 2011 prices).
- For the Rail Tunnel Eastern family, passive provision would be provided by a pair of turnout caverns between Old Oak Common and Euston and is estimated to cost £103 million (at 2011 prices).
- If additional future impacts are considered unacceptable, the only alternative passive provision would be to construct the full tunnel length (but with no fit-out, tracks or other rail systems) during HS2 Phase One, starting from Old Oak Common Station and emerging within the Camden area. The construction cost has been estimated at £265 million to £355 million, which represents the civil engineering costs of building the tunnel with no fit-outs, track or other rail systems.

1.6.28 However, there are a number of disbenefits of passive provisions:

- For the £42 million tunnel stub option, when the full HS2-HS1 link is eventually constructed, tunnel boring would need to commence at the tunnel portal end in Camden, rather than at the Old Oak Common end. All excavated materials would have to be taken out from the tunnel portal location in Camden as well. This would lead to increased local traffic disruption, land take, additional property demolition and associated compensation.
- The turnout caverns would need to be built via a shaft. If the current shafts could not be used, new shafts would need to be located and powers obtained. The caverns would need to be built in advance of tunnel boring machines arriving from Old Oak Common. This might have programme implications as the Euston tunnels are on the critical path.
- For both tunnel stub and turnout cavern options, passive provision defers all the disbenefits noted above to a later date, as well as deferring construction costs.
- The cost of passive provision would be either £42million or £103 million, with no benefit until the link is constructed and becomes operational.

- 1.6.29 However, these factors should be considered in the context of long-term infrastructure and other strategic goals. Passive provision potentially offers the benefit of building in future adaptability, and then developing improvements alongside the existing solutions in the baseline scenario. Without adequate passive provision, the levels of disruption to rail services particularly resulting from construction, impacts on the local community and businesses as well as increased costs, could be considered unacceptable and could irreversibly compromise any consideration of a HS1-HS2 rail link.
- 1.6.30 An important consequence of not providing adequate passive provision would be disruption to HS2 services resulting from enabling works:
- Old Oak Common Station layout changes;
 - new international support services;
 - reconfiguring ventilation shafts;
 - new track works; and
 - integration with existing rail systems such as signalling and traction.
- 1.6.31 Planning and executing this sequence of required additional works could take three or four years, in parallel with running the HS2 operation. The consequent disruption to HS2 operations is unclear without further detailed studies, but several extended periods of service interruption would be required. Negotiating and planning these possessions and closures with train operating companies could take between three and five years.
- 1.6.32 For local communities and business, the absence of adequate passive provision would increase the rail link project footprint. Additional infrastructure works would be required, leading to the demolition of more residential and commercial properties in Camden.

1.7 Rail options alternative (including Petition options)

- 1.7.1 The petition process in response to the November 2013 hybrid Bill has raised a number of rail options not previously considered. These can be summarised as:
- a West London Line option - using the West and South London Lines, Brighton Main Line and Ashford Lines to link Old Oak Common with Ashford;
 - a Kings Cross HS2 Terminal option - running HS2 services into Kings Cross station rather than Euston station;
 - a Euston Cross option - trains arriving at Euston from the west, with an underground interchange station between Euston and St Pancras, and trains going east leaving from St Pancras in a tunnel to Stratford and HS1; and
 - the Greengauge 21 proposal - a high-capacity link between Stratford and Old Oak Common, with additional connections from Old Oak Common to Heathrow or the Chilterns.
-

West London Line (WLL) Option

1.7.2 This option would use the West and South London Lines, Brighton Main Line (BML) and Ashford Lines to link Old Oak Common and Ashford stations, as shown in Appendix E. This option would suffer from the following issues:

- Most of these routes are already operating at or near to full capacity and could not therefore accommodate HS2 trains.
- To connect to the WLL, a 900 metre ramp would be required along with grade-separated junctions onto the WLL.
- Station platforms in Sussex or Kent cannot accommodate 400m trains; trains of this length would block a number of junctions at the rear when standing at signals, which would be likely to cause significant operational disruption.
- Rolling stock configuration and door positions mean it takes much longer for passengers to board high speed trains, and longer times spent at stations.
- If these trains call at intermediate stations, immigration and customs controls would be required at Ashford station.
- Trains would need to be run as single 200m classic-compatible sets as far as Ashford, where they would need to be combined with another 200m set. At present, only three services per day operate between Ashford and Paris, and one per day to Brussels. (It is not economical to run a 200 metre train through the Channel Tunnel, where track access is charged according to paths.) It is doubtful that there is sufficient patronage to fill a 200m set from Ashford on a frequent basis.
- Rolling stock using this route would need to be equipped for dual voltage (25kV AC overhead and 750V DC third rail). The only high speed stock capable of this is the current Eurostar fleet, and it will be life-expired by 2026. At present, HS2 plans to procure rolling stock with 25 kV AC traction power.
- On the assumption that paths over the WLL and BML to East Croydon are available and at the same speed as stopping services, GJT between Old Oak Common and Ashford indicate that this option would be around 10 minutes faster than the baseline comparator of walking between Euston and St Pancras. No formal cost-benefit exercise has been undertaken for this scheme, but the combination of operation limitations, effects on other services, and marginal journey-time benefits strongly suggest that this scheme would perform poorly.

Kings Cross HS2 terminal option

1.7.3 HS2 Ltd reviewed this option as part of the 2009 Route engineering study. Documenting the full range of locations considered for the HS2 London Terminal, the study included a review of a range of options located in the Kings Cross Lands and at St Pancras. Following appraisal by

HS2 Ltd, Euston was considered the preferred terminal location. Options terminating at St Pancras or Kings Cross were not progressed.

Euston Cross option

1.7.4 This option was reviewed as part of the Euston Cross study, completed in December 2013. The proposed Euston Cross station site is north of the proposed Crossrail 2 station. The extent of tunnelling required - including running lines and turnback sidings, and the requirement for an APM connection between the Euston Cross station and Euston underground station as part of the scheme means that co-ordinating with the Crossrail 2 proposals would be highly challenging.

1.7.5 The Euston Cross proposals assume that the main running tunnels would be diverted to an alternative alignment. This would result in significant impacts to the track arrangements at Old Oak Common. Further assessment would be required to understand the feasibility and costs of achieving this level of functionality.

1.7.6 The Euston Cross Study concluded that:

"whilst the concept does permit through services from Kent to the North and there are operational advantages associated with reducing the number of trains that terminate in Central London, there are significant issues...[including]:

- *Additional journey time for the majority of users who are projected to be travelling to central London destinations and require access to the Underground and other methods of surface travel.*
- *Lack of feasible connection point to HS1 leading to 22km of additional tunnelling and an additional station at Stratford with associated capital and operating cost penalties.*
- *Increased demolition of residential units compared with the proposed scheme."*

1.7.7 On this basis, the Euston Cross was not progressed.

Greengauge 21 proposal

1.7.8 Documents from Greengauge 21 (Travel market demand and the HS1-HS2 link, 2013 and HS1-HS2 connection: A way forward, 2014) promote the benefits of a high capacity (more than 3tph) connection between Stratford International and Old Oak Common, with additional connections from Old Oak Common west to Heathrow or the Chilterns.

1.7.9 This full level of functionality is not achieved by any of the HS2-HS1 rail options reviewed above. A twin-track tunnelled solution would meet the Sponsor's requirement and support further service provision, with little impact on existing NLL rail operations since it would avoid any works in the central Camden area.

1.7.10 Patronage forecasts by Greengauge 21 suggest a potential one-way daily international demand of 10,900 trips and one-way daily domestic demand of 43,500 trips. This corresponds to around 2,700 morning peak period international passengers and 14,500 morning peak

period domestic passengers. Greengauge 21 provides no indication of the likely train frequencies required to support this level of demand or whether there would be sufficient capacity on the rail network.

- 1.7.11 Some of the Greengauge 21 assumptions are inconsistent with HS2 Ltd's work, while other assumptions are unknown but could have significant impacts. For instance:
- Projections include passengers accessing Heathrow via HS2. In reality, HS2 will not serve Heathrow.
 - It is unclear whether they have assumed a Crossrail 1 station at Old Oak Common. When HS2 and Crossrail 1 are operational, passengers will have access to a high-frequency service between Stratford and Old Oak Common with journey times of under 25 minutes.
 - It is unclear how the connection between Stratford Station and Stratford International has been modelled. The connection requires a journey by DLR or on foot.
- 1.7.12 The Greengauge 21 proposal presents no cost-benefit analysis and no specific environmental impact study is available. Based on the options presented above, an analysis of these issues would also need to consider the additional costs for the proposed western connections from Old Oak Common and the works required to connect any of the longer-distance tunnelled options to Stratford International.
- 1.7.13 On the basis of the Euston Cross analysis, this would require an additional station at Stratford. In supporting the construction of new station facilities, impacts on the Stratford area could be substantial and would require detailed review.

1.8 Automated people mover, elevated travelator and walkway options

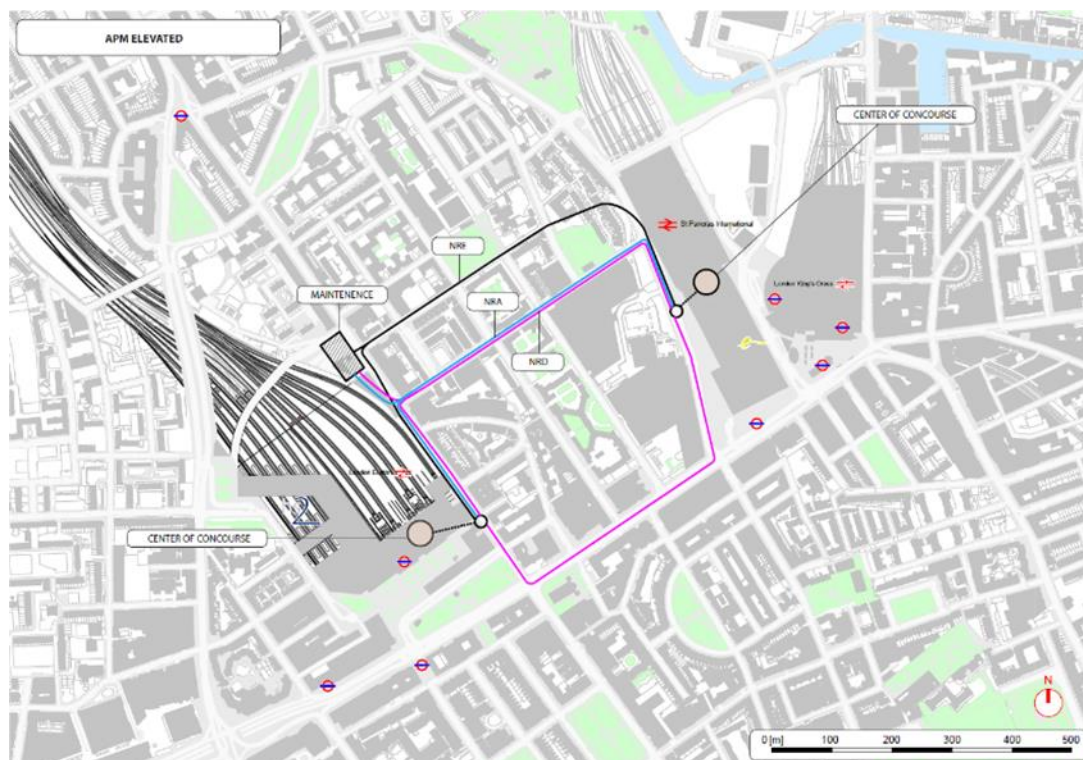


Figure 3: Automated people mover, elevated travelator and walkway options

1.8.1 APM and elevated travelator/elevated walkway options linking Euston and St Pancras stations were developed in 2010 as potential alternatives to the HS2-HS1 rail link. International passengers would travel from the north to Euston on HS2 services, before using the APM to transfer between Euston and St Pancras where they would catch a HS1 train. A number of sub-surface or elevated options were developed with three different styles of route.¹³ These were grouped into the following APM families:

- sub-surface APM options using dedicated tunnels;
- elevated APM options above road level; and
- elevated travelator and elevated walkway options.

1.8.2 We have assumed that all options would be available to local users as well as international passengers (APM options offer faster journey times so attract greater local patronage), and that international passengers would require customs and security checking at St Pancras station. Costs and benefits for APM options are set out in Table 4: Costs and benefits – HS2-HS1 APM options.

¹³ Grade-level options were discounted due to their severance impacts.

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Table 4: Costs and benefits – HS2-HS1 APM options

Family	Option group	Cost £m 2011	Patronage AM peak ¹⁴	Benefits £m 6o PVB	GJT compared with baseline
APM options	Sub-surface APM	£212-£248	3,250-3,800	£225 ¹⁵	12 minute saving
	Elevated APM	£177-£226	3,250-3,800	£225	12 minute saving
Elevated travelator/Elevated walkway options	Travelator/Walkway	£120/£85	2,250-2,800	Unknown	5 minute saving (travelator only)

Sub-surface APM options

- 1.8.3 The APM routes would be located within cut-and-cover tunnels rather than a bored tunnel. The bored tunnel option was rejected during the 2010 work because the tunnel required a depth of more than 20 metres, and the need for shafts at either end would mean property acquisition and associated disruption.
- 1.8.4 The maximum frequency for an APM system is likely to be one shuttle every two to three minutes in each direction. This equates to approximately 20-30 shuttles per hour in each direction and gives a capacity of around 10,000 passengers per hour. Based on current analysis, up to 800 international passengers are forecast to require the link during the peak three-hour period. The system would be open to the public and could be heavily used by non-international passengers, with potential local usage estimated at 3,000 passengers for the three-hour peak. There would be GJT benefits of around 12 minutes over existing options such as walking or taking the underground.
- 1.8.5 Benefits of a sub-surface APM system linking Euston and St Pancras include a relatively quick and frequent service which could also provide journey opportunities to non-international travellers. Previous analysis by HS2 Ltd estimated the benefits of the system at around £225 million (for HS2 passengers) and indicated that the majority of benefits would accrue from non-international passengers. On this basis, any economic case for an APM between Euston and St Pancras would largely be driven by improved links for local commuters rather than improved links between HS2 and HS1.
- 1.8.6 The sub-surface options would operate along non-rail corridors and in theory would not impact on existing rail operations. Whilst construction at the Euston and St. Pancras ends would impact rail passengers, it is assumed that there would be no impact on rail services at these two stations.
- 1.8.7 Elements of the sub-surface APM are incompatible with the hybrid Bill design, including conflicts between the proposed APM maintenance area and the Parcels Deck delivery and

¹⁴ One-way flow in the peak direction.

¹⁵ Source: *High Speed Rail - London to the West Midlands and beyond – A report to Government by High Speed Two Limited – Supplementary Report*, September 2010.

servicing area, the bus layover area and the need to relocate a permanent sub-station that provides power for Euston station. The hybrid Bill design does not make any allowance in terms of passive provision, for a future APM system.

- 1.8.8 The sub-surface options could result in significant disruption to the local community during construction - including road closures, bus diversions, construction traffic, loss of access to properties, noise and dust, severance to communities, and disruption caused by the cut-and-cover construction, potentially making properties along the route uninhabitable during construction (and possibly permanently). London Borough of Camden has indicated that it would strongly oppose an APM system on environmental and community impact grounds.
- 1.8.9 The GJT for APM is around 12 minutes shorter than the baseline comparator but approximately 55 minutes longer than the rail options when measured between Old Oak Common and Stratford International stations.
- 1.8.10 Initial construction costs are estimated at between £212 million and £248 million depending on route alignment, including allowances for risk and optimism bias. No data are available on estimated operating costs or revenues.

Elevated APM options

- 1.8.11 Elevated APM options could operate along Phoenix Road or Polygon Road. As these are non-rail corridors, there would be no impact on existing rail operations. Whilst construction at the Euston and St. Pancras ends would impact rail passengers, it is assumed that there will be no impact on rail services at these two stations.
- 1.8.12 Elements of the elevated APM are incompatible with the hybrid Bill design. In particular:
- The proposal to terminate the guideway at Euston station at high level, above the classic platforms, would be incompatible with the roof height above the reconstructed Parcels Deck in the hybrid Bill design.
 - The proposed APM maintenance depot area to the north of Euston station would be incompatible with vehicle access to the Parcels Deck.
 - The relocation of a permanent sub-station providing power for the station, and the bus layover area.
 - The hybrid Bill design does not make any allowance, in terms of passive provision, for a future APM system.
- 1.8.13 The forecast demand for a link would be similar to the sub-surface option, namely up to 800 international passengers during the peak three-hour period. Again, the system would be open to the public and could be heavily used by non-international passengers.
- 1.8.14 Elevated people-mover options on either Phoenix Road or Polygon Road would have substantial local environmental impacts in the Somers Town residential area. The Polygon Road route would require the demolition of residential properties between Purchase Street in Kings Cross and Midland Road, as well as land take from two open spaces. The Phoenix Road-

Brill Place route would affect a major development for a medical research facility adjacent to the British Library. London Borough of Camden has indicated that it would strongly oppose an APM system on environmental and community impact grounds.

- 1.8.15 The elevated APM would cause major visual intrusion by running adjacent to the upper-storey windows of residential properties, schools, offices and business premises. This would be more acute for the Polygon Road option as it is narrower than Phoenix Road. The Phoenix Road-Brill Place route would affect the setting of three Grade II listed buildings. Both alignments would also require the removal of established trees, which form the 'green' part of the streetscape of the built-up Somers Town area.
- 1.8.16 Noise effects could be partially mitigated through modern design and mitigation measures but the elevated nature and close proximity of these options suggest that local properties would still be affected by operational noise and vibration for each option.
- 1.8.17 Initial construction costs are estimated at between £177 million and £226 million depending on alignment route, including allowances for risk and optimism bias but excluding costs for property acquisition and compensation. These compare to benefits to international passengers of £225 million.

Elevated travelator and elevated walkway options

- 1.8.18 This family of options would link Euston and St Pancras stations via upgraded pedestrian facilities:
- elevated travelator; or
 - elevated walkway.
- 1.8.19 The travelator option comprises a system of elevated airport-style travelators at either 200m or 300m in length. This would provide a pedestrian route between the two stations, with a lobby-style area at high level on Eversholt Street allowing access to Euston Station, and access to the concourse area via escalator. At St Pancras International a travelator of approximately 60m in length would carry passengers south from Phoenix Road to the high-level Midland Main Line concourse area. The elevated walkway option would use similar alignment and station access arrangements. Allowing for two-way operation, a travelator system would need to be around six or seven metres wide and a walkway around four or five metres wide.
- 1.8.20 The operational capacity of the elevated travelator, including allowances for passengers with luggage, would exceed the walkway option and could be in the order of 4,000 passengers in each direction per hour.
- 1.8.21 Both the elevated travelator and walkway would suffer from a similar degree of visual intrusion as an APM system, although associated construction issues would be less severe than for an APM. London Borough of Camden has indicated that it would strongly oppose any travelator system on environmental and community impact grounds.

- 1.8.22 The GJT for travelator and elevated/walkway options is similar to the baseline comparator but is around 70 minutes longer than the rail options when measured between Old Oak Common and Stratford International stations.
- 1.8.23 International demand for a travelator or walkway is assumed to be similar to demand for an APM system, i.e. up to 800 international passengers during the peak period with the travelator and walkway options open to other passengers. The GJT benefits of these options are around seven minutes lower than the APM-based options, reducing their attractiveness for local users.
- 1.8.24 Initial construction costs have been estimated at £120 million for an elevated travelator and £85 million for an elevated walkway, including risk and optimism bias.

1.9 Appraisal of options

- 1.9.1 Options have been appraised using HS2 Ltd's Route development appraisal template. This compares how these schemes perform against the hybrid Bill baseline comparator. It uses a typical five-scale process, shown in Figure 4: Appraisal summary table, to indicate whether the option being assessed performs better, worse or similarly to the baseline comparator. Figure 5: Quantified appraisal summary table provides a quantified version of this table.
- 1.9.2 The key conclusions emerging from the review are:
- Enhanced street-level walking routes between Euston and St Pancras would have the lowest cost of all options but would offer no journey time benefits over the baseline comparator. However, sympathetic development of these routes could offer potential environmental benefits with possible community support. This option might overcome a number of cost, feasibility and environmental disadvantages associated with the rail options. Enhanced street-level walking routes could be supported by taxi use for mobility-impaired passengers or, potentially, a shuttle bus service, although this has not been investigated at this stage.
 - Crossrail 2 is, at present, an uncommitted scheme but it would provide a link between Euston and St Pancras. However, there would be no journey time benefits, and discussions with TfL regarding interchange between Euston and St Pancras indicate that the preference would be for any between-station movements of this type to be managed outside the station. TfL and HS2 Ltd would need to work closely to further explore this option.
 - All rail solutions provide significant journey time savings but have high construction costs and also suffer from operational and environmental disbenefits. Most of the rail schemes reviewed have been previously rejected. On the basis of this review, the conclusion is that there is no viable rail option capable of meeting strategic aspirations while successfully addressing stakeholder concerns and value-for-money criteria.
 - Passive provision could be provided and has been suggested in a number of petitions

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to the hybrid Bill. This would allow for rail options to be deferred to a later date. Construction costs have been estimated at either £42 million or £103 million, depending on the provision opted for. Passive provision would protect future opportunities for delivering a high capacity link at a later date when the economic case might be stronger, but would defer the associated disbenefits of rail options. It would also result in increased cost and environmental/social impacts when the link is eventually constructed.

- APM and elevated travelator/elevated walkway options between Euston and St Pancras are significantly less expensive than rail options but still have construction costs of around £200 million or more, for GJT savings of around 12 minutes or less when compared to the baseline comparator. Potential users include a high volume of local pedestrians but the impact of these proposals on the local community includes temporary major adverse impacts during construction for tunnelled systems, and permanent major visual intrusion issues for elevated systems during operation.
- Petition items include the West London Line option, which shows a major worsening across most criteria with limited improvement in GJT over the baseline. It could provide benefits to other users but international and other passengers would not be separated.
- Greengauge 21 promotes a high speed, high capacity (more than 3tph) connection between Stratford International and Old Oak Common, with additional connections from Old Oak Common west to Heathrow or the Chilterns. Forecasts of demand include international and domestic passengers and are considerably higher than HS2 Ltd and TfL forecasts. It is unclear what level of service in terms of trains per hour would be needed to achieve sufficient capacity. There are no cost estimates or environmental impact studies available for the Greengauge 21 proposals.

---	Major worsening on the comparator scheme
--	Minor worsening on comparator scheme
0	Neutral / no change to comparator scheme
+	Minor improvement on comparator scheme
+++	Major improvement on comparator scheme
N/A	Not applicable

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	Option Family	Cost	Construction Feasibility	Operational Capability/ Capacity	Potential Demand (International)	Journey Time Incl. no. of interchanges	Environmental impact	Impacts on other users (Domestic & Local)	Impact on communities	Compatibility with Passive Provision	Custom & Passport requirements	Risks
Baseline Comparator - Hybrid Bill scheme with HS2-HS1 link removed consistent with Secretary of State's Decision												
Rail Options Central & Eastern	Rail tunnel plus shared surface operation	---	---	+	+++	+++	---	---	--	O	+	---
	Rail tunnel plus segregated surface operation	---	---	+++	+++	+++	---	+	---	O	+	---
	Rail tunnel between Old Oak Common and Camden	---	---	+++	+++	+++	---	+	---	O	+	---
	Longer distance Rail Tunnel between Old Oak Common and Stratford or beyond	---	---	+++	+++	+++	---	+	--	O	+	---
Rail Options Alternatives	Euston Cross / Passive Provision	---	---	+++	+++	+++	---	--	---	N/A	O	---
	Kings Cross Tunnels	Reviewed during route selection and not progressed										
	West London Line	Unknown	---	---	+	O	Unknown	---	Unknown	N/A	O	---
	Greengauge 21 Proposals	---	---	+++	+++	+++	---	+	--	O	+	---
APM & Travelator Systems	APM Sub-surface	--	---	+	O	+	--	+++	---	N/A	O	---
	APM Elevated	--	--	+	O	+	---	+++	---	N/A	O	---
	Elevated Travelator/Elevated Walkways	--	--	+	O	+	---	+++	---	N/A	O	---
Enhanced Walk Options at Euston	Use of Crossrail 2 station as walking route	O	O	O	O	O	O	--	O	N/A	O	O
	Enhanced street level walking route	O	O	O	O	O	+	+	+	N/A	O	O

Figure 4: Appraisal summary table

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Option Family		Cost	Construction Feasibility	Operational Capability/ Capacity	Potential Demand (International)	Journey Time Savings Incl. no. of interchanges	Environmental impact	Impacts on other users (Domestic & Local)	Impact on communities	Compatibility with Passive Provision	Custom & Passport requirements	Risks
Baseline Comparator - Hybrid Bill scheme with HS2-HS1 link removed consistent with Secretary of State's Decision												
Rail Options Central & Eastern	Rail tunnel plus shared surface operation	£580m- £890m	---	+	1300/3 hrs	70 minutes	---	---	--	O	+	---
	Rail tunnel plus segregated surface operation	£610m to £630m	---	+++	1300/3 hrs	70 minutes	---	+	---	O	+	---
	Rail tunnel between Old Oak Common and Camden	£653m to £995m	---	+++	1300/3 hrs	70 minutes	---	+	---	O	+	---
	Longer distance Rail Tunnel between Old Oak Common and Stratford or beyond	£2,785m to £3,420m	---	+++	1300/3 hrs	70 minutes	---	+	--	O	+	---
Rail Options Alternatives	Euston Cross / Passive Provision	---	---	+++	1300/3 hrs	+++	---	--	---	N/A	O	---
	Kings Cross Tunnels	Reviewed during route selection and not progressed										
	West London Line	Unknown	---	---	+	O	Unknown	---	Unknown	N/A	O	---
	Greengauge 21 Proposals	---	---	+++	+++	70 minutes	---	+	--	O	+	---
APM & Travelator Systems	APM Sub-surface	£212m to £248m	---	+	800/3hr	12 minutes	--	+++	---	N/A	O	---
	APM Elevated	177m to £226m	--	+	800/3hr	12 minutes	---	+++	---	N/A	O	---
	Elevated Travelator/Elevated Walkways	£120m/ £85m	--	+	800/3hr	5 minutes	---	+++	---	N/A	O	---
Enhanced Walk Options at	Use of Crossrail 2 station as walking route	O	O	O	800/3hr	O	O	--	O	N/A	O	O
	Enhanced street level walking route	£2.5m	O	O	800/3hr	O	+	+	+	N/A	O	O

Figure 5: Quantified appraisal summary table

Acronyms

APM	Automated People Mover
CFA	Community Forum Area
DfT	Department for Transport
GJT	Generalised Journey Time
HS	High Speed
HS1	High Speed 1
HS2 Ltd	High Speed 2 Ltd
LU	London Underground
NPV	Net Present Value
NR	Network Rail
NLL	North London Line
OOO	Old Oak Common
OPEX	Operating Costs
PCR	Post-Consultation Route
PVB	Present Value of Benefits
PVC	Present Value of Costs
RODs	Rolling Origin Destination survey
SoS	Secretary of State
TfL	Transport for London
TPD	Trains per day
TPH	Trains per hour
WCML	West Coast Main Line
WLL	West London Line

Glossary

Term	Definition
Automated People Mover	Fully automated passenger transit system featuring vehicles that operate on guideways with exclusive right-of-way.
Community Forum Area	Discrete geographical areas along the HS2 route defined in the November 2013 Environmental Statement.
Generalised Journey Time	A weighted sum of time and other costs of travel, which can be measured in units of money or (preferably) time.
Net Present Value	The difference between the present value of costs and the present value of benefits. NPV is used to analyse the profitability of an investment or project. Estimated current value of a future amount to be received or paid out, discounted at an appropriate rate. NPV provides a common basis for comparing investment alternatives.
Present Value of Benefits	Estimated current value of future benefits, discounted at an appropriate rate.
Present Value of Costs	Estimated current value of future costs, discounted at an appropriate rate.
North London Line	A railway line of the London Overground, which passes through the inner suburbs of north London.
Operating Costs	All costs associated with operating and maintaining a railway or other transport system.
Post-Consultation Route	Route for HS2-HS1 link using a combination of tunnel and shared surface operation with the North London Line.
NLL Enhanced Route	Route for HS2-HS1 link using a combination of tunnel and segregated surface operation with the North London Line.
PLANET framework Model	Bespoke Department for Transport model used to forecast demand, revenue and benefits impacts of HS2 on national rail services, to inform the business case for the project.
Rolling Origin Destination survey (RODs)	A rolling programme to capture information about journeys on the LUL network.
Passive provision	Measures that allow for or facilitate the future introduction of additional infrastructure. This could range in scope from adopting design configurations compatible with proposed additional infrastructure, to up-front delivery of elements of the planned infrastructure to enable construction of the full scheme at a later date with limited impacts.
Segregated tunnels	Tunnel options that include segregated (i.e. dedicated high speed/conventional) tracks for any surface-level components.
Bored tunnel	Tunnel with circular cross-section constructed using a tunnel boring machine.
Cut-and-cover tunnels	Tunnel constructed using methods where a trench is excavated from above and roofed with an overhead support system strong enough to carry the load of what is to be built above the tunnel.

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Parcels Deck	Part of the existing Euston station, this deck structure above the platforms at the north of the station is currently used as part of the servicing area for Euston station.
Interchange penalty	A fixed time penalty applied to the number of times a passenger is required to transfer between different public transport services. It reflects the perceived cost of changing services.
Rolling stock configuration	Layout of a train including carriage number and length, door position, number of seats and standing area.

2 Introduction

2.1 Context

- 2.1.1 In November 2013, the Government deposited a hybrid Bill with Parliament to secure the powers to construct and maintain Phase One of HS2 between London and the West Midlands. The hybrid Bill included provision of a link between Old Oak Common station and the High Speed 1 connection (the HS2-HS1 link) to the north of St Pancras station. This would link the two high speed railways and facilitate direct high speed services from across Britain to mainland European destinations, via the Channel Tunnel, without stopping at St. Pancras International or Euston stations. Old Oak Common would provide the stop in London for these international services.
- 2.1.2 The development of rail options for the HS2-HS1 link began in 2009 and culminated in January 2012 with an announcement of the Post-Consultation Route (PCR) option. The PCR option ran in-tunnel between Old Oak Common and a portal north-west of Primrose Hill, and then through Camden, sharing tracks with the North London Line (NLL). However, the Sponsor's requirement of three trains per hour (3tph) could not be achieved without significant implications for passenger and freight services on the NLL. For these reasons, Network Rail (NR) considered these options to be operationally non-viable. The link scheme was instead developed to provide segregated running from the NLL. This culminated in the 'NLL Enhanced Route,' which was the scheme proposed in the hybrid Bill.
- 2.1.3 The first Higgins Report HS2 Plus came out in March 2014. This concluded that the proposed HS2-HS1 link in the hybrid Bill was the most cost-effective solution to delivering three trains per hour but noted that the proposal had operational limitations. It also noted adverse impacts on the West Coast Main Line (WCML), freight capacity, future commuter growth on the NLL, and on the community of Camden. Removing the HS2-HS1 link was estimated to reduce the Phase One forecast cost by £700 million (including risk provision). The HS2 Plus report concluded that it would be better to consider alternatives to the link that could deliver the link's benefits without compromising existing services. In response to HS2 Plus, the Secretary of State announced his decision to remove the HS2-HS1 link from the hybrid Bill.
- 2.1.4 The Secretary of State continues to believe that there is a good strategic case for links to the continent and has asked HS2 Ltd to work with the Department for Transport (DfT) to explore alternatives to the link that would improve connections to the continent. Euston and St Pancras stations are 750 metres apart and are one stop apart on the Northern and Victoria lines. HS2 Ltd appointed Arup and Mott MacDonald in December 2014 to review all the options previously considered for connecting HS2 to HS1 and the continent, together with a high-level review of any options emerging from the HS2 petition process, and any further options not covered previously.

2.2 Objectives of this review

2.2.1 This review includes:

- A round-up of rail options previously proposed for connecting HS2 to HS1, including how these options could be delivered at a later date and whether passive provision would be required to enable this. This review was undertaken by Mott MacDonald.
- An assessment of the options available to improve non-rail pedestrian links between Euston and St. Pancras, including APM and travelator systems. This was undertaken by Arup.
- A high-level review of not previously considered options proposed in petitions to the hybrid Bill. This was undertaken by Arup.
- A high-level review of any options not considered in 1, 2 or 3, including any opportunities provided by Crossrail 2 proposals. This was undertaken by Arup.

2.2.2 The review also considered the following constraints:

- For rail and non-rail options, no new options, design, analysis or modelling were to be undertaken.
- Options should consider the requirements for immigration and customs controls for travel to and from the continent.

2.3 Options reviewed

2.3.1 Initial review of the options indicated over 30 variants. A full list of options is provided in Appendix B, with a summary under broad headings in Table 5: Options reviewed.

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Table 5: Options reviewed

Option family	Family sub-group
Rail Options Central	Rail tunnel plus shared surface operation
	Rail tunnel plus segregated surface operation
	Rail tunnel between Old Oak Common and Camden
Rail Options Eastern	Longer distance Rail Tunnel between Old Oak Common and Stratford or beyond
Rail Options Alternative	West London Line option ¹⁶
	Greengauge 21
	Euston Cross ¹⁷
	Kings Cross HS2 terminal ¹⁸
Automated People Mover (APM) and travelator systems	Elevated APM
	Sub-surface APM
	Elevated travelator or elevated walkway
Enhanced Walk Options at Euston	Enhanced street level walking route
	Use of Crossrail 2 station as walking route

2.4 Structure of this review

- 2.4.1 The review first sets out the methodology underlying the assessment of options, before describing the possible demand and benefits of an HS2-HS1 link. The baseline comparator scenario is described next. After that, each group of options is assessed in turn, namely Central and Eastern Rail Options, Alternative Rail Options, Automated People Mover and Travelator options, and Enhanced Walk options at Euston. A summary of the option assessment is provided in the final section.
- 2.4.2 The documents and other assessment tools and information relating to the HS2-HS1 link that we used in preparing this review are listed in Appendix A. They are also summarised in Figure 6: HS2-HS1 link timeline, which provides a timeline of the reports considered against the development of the HS2-HS1 link.

¹⁶ Raised as Petition items.

¹⁷ Raised as Petition items.

¹⁸ Raised as Petition items.

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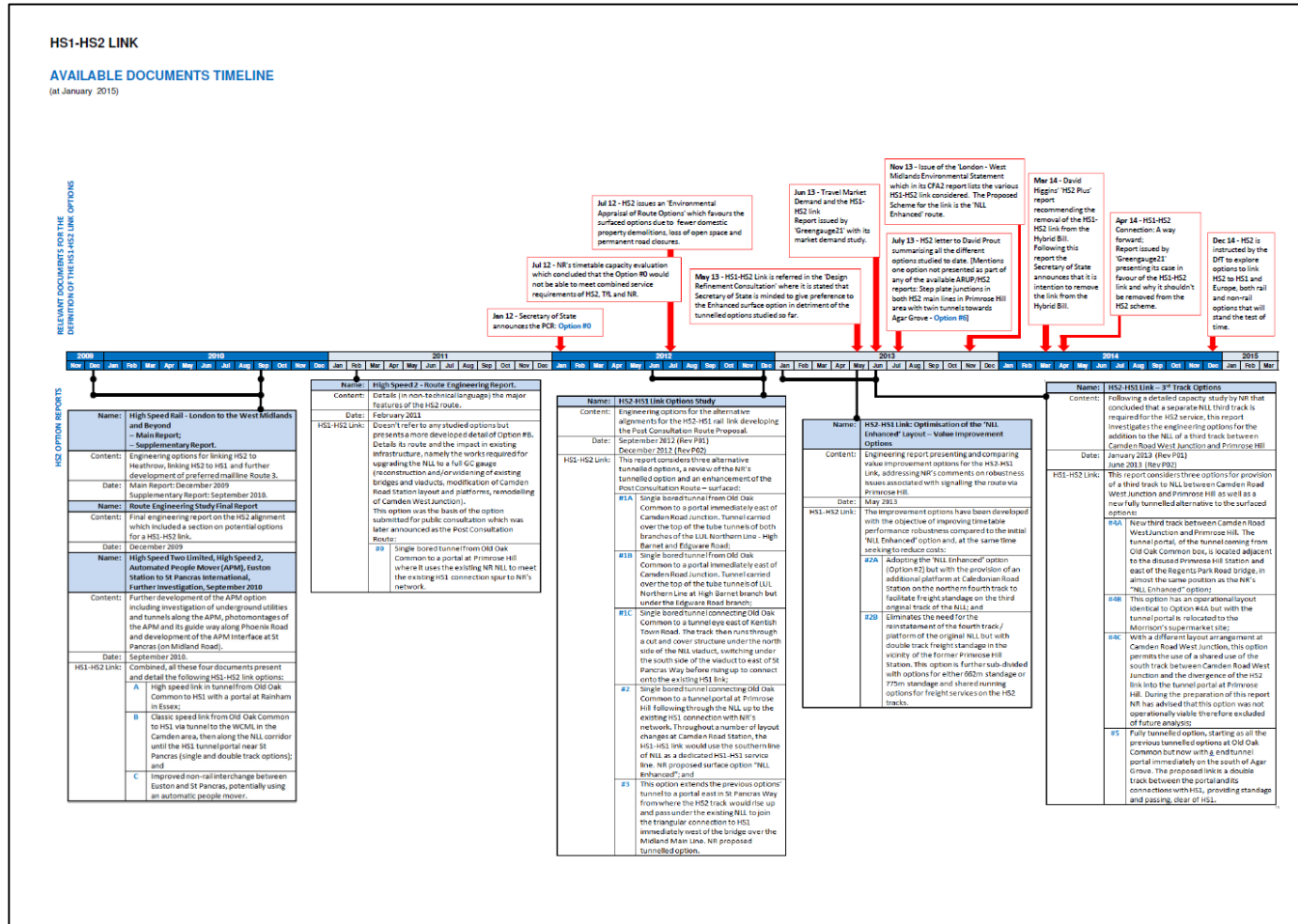


Figure 6: HS2-HS1 link timeline

3 Appraisal framework and methodology

3.1 Overview

3.1.1 We have appraised the wide range of options by measuring them against a baseline comparator scenario that reflects the Secretary of State’s decision to remove the link from the hybrid Bill. The baseline comparator scenario is ‘HS2 Phase One with no HS2-HS1 link’ and reflects how international travellers might transfer between HS2 and HS1 services in the future, given committed infrastructure. These choices comprise walking, bus, underground (Victoria or Northern Line) or taxi services between Euston and Kings Cross St Pancras stations. The hybrid Bill scheme also includes a sub-surface walk link between Euston and Euston Square stations which will provide a step-free route to the Circle, Metropolitan and Hammersmith & City Lines. Kings Cross St Pancras station is one stop from Euston Square station. Walk routes between Euston and St Pancras would be via Euston Road, Phoenix Road or Polygon Road.

3.1.2 We set up an appraisal framework to review the broad set of options put forward, using a set of assessment criteria. These provide an appropriate level of detail based on the latest available data. Some adjustment has been undertaken, for example bringing costs to a common base including consistent application of contingency and optimism bias. However, further design, analysis and modelling of emerging options is beyond the remit of this review.

3.1.3 Following discussions with the DfT and HS2 Ltd, we based the appraisal process on that set out in the HS2 – Route development appraisal template. This uses the hybrid Bill without the HS2-HS1 link as the baseline comparator. The precise headings of the assessment criteria were adjusted to reflect the differing stages of option development available to us. The assessment requires:

- a ‘Qualitative Impact Description and/or Quantitative Assessment,’ comprising a brief written assessment to draw out the key issues, including any quantitative assessment made; and
- a ‘Rating’ column, which should be a colour-coded assessment of the option based on the following Option Appraisal Assessment Criteria:

---	Major worsening on comparator scheme
--	Minor worsening on comparator scheme
0	Neutral / no change to comparator scheme
+	Minor improvement on comparator scheme
+++	Major improvement on comparator scheme
N/A	Not applicable

3.2 Appraisal framework and methodology

3.2.1 The appraisal criteria used in the framework are described below.

Cost

3.2.2 For rail and non-rail options, 'cost' refers to the most recently available cost, adjusted to a consistent 2011 prices base, with comparable levels of contingency and optimism bias, and engineering cost, as well as indirect management costs, plus risk and opportunity allowances. It excludes property acquisition costs and compensation, which could be significant and may vary between options.

3.2.3 At this stage, no discounting has been undertaken to reflect the profile of costs over time for the different options. Further analysis would be required in order to present these costs as a present value of costs (PVC).

Construction feasibility

3.2.4 We identify specific construction feasibility issues; where these relate to site availability, we assume that the necessary sites are available. The implications of this are further flagged under community impacts.

Operational capability

3.2.5 This covers the HS1-HS2 link high speed service capacity for rail options and service specification, likely capacity, and any constraints for other options.

Potential demand

3.2.6 The potential demand for a HS2-HS1 link is an important consideration. This review takes demand numbers for rail and non-rail options from existing documentation on international passengers and, where the option supports the introduction of non-international services, on domestic rail passengers. For links between Euston and St Pancras, the demand comprises international passengers, domestic passengers and an allowance for background or local demand, including local pedestrian movements. Any new modelling and analysis is outside the remit of this report.

Compatibility with passive provision

3.2.7 For the relevant options, we provide a commentary on the works necessary to enable an HS2-HS1 link to be constructed at a later date in the HS2 programme, which would minimise future impacts on HS2 infrastructure and rail operations. We provide a commentary on the costs of passive provision and the deferment of costs and benefits.

Benefits

3.2.8 We articulate benefits largely as common journey times between two common points, taking into account in-vehicle time, interchange time, walk time, wait time, time at immigration and customs controls, and so on. We have measured these journey times between Old Oak Common and Stratford. Most options must pass between these two points, with the

exception of some of the longer tunnelled routes. For those options, we undertook a further assessment of journey times between Old Oak Common and Ashford.

- 3.2.9 In line with the guidance in WebTAG Unit M3.2, we have expressed journey times as Generalised Journey Times (GJT). These times combine different attributes, with each attribute being given its own weight. The weightings convert components to common units of time and are chosen to ensure that the relative importance of each component for passengers is reflected. The attributes selected were:
- in-vehicle time (weighting may vary by mode/vehicle type);
 - walk transfer time (between public transport stops);
 - interchange wait time (time spent waiting for subsequent services, whether local or international); and
 - interchange penalty (a fixed penalty based on the number of transfers).
- 3.2.10 In line with the HS1/HS2 link international demand forecasting and appraisal report of February 2014, fares, access times and frequency of service at origin are excluded from the headline GJT calculation. For each of these selected attributes, the weights recommended in WebTAG are:
- in-vehicle time = 1.0
 - wait time = 1.5 to 2.5
 - walk time = 1.5 to 2.0
 - interchange penalty = 5 or 10 minutes.
- 3.2.11 In selecting a definitive value for these ranges of weights, we referred to TfL's Railplan model and DfT's PLANET model. These are largely consistent with each other (and are as set out below), with the exception of the interchange penalty which varies by mode and differs for each model. For National Rail the interchange penalties are 3.5 minutes in PLANET and 7.0 minutes in Railplan. In contrast, the HS1/HS2 link international demand forecasting and appraisal report of February 2014 applies a 30-minute interchange penalty for each rail-to-rail interchange but does not apply a penalty at the level of interchange to local transport modes within London. The potential mix of international and domestic passengers also suggests a somewhat lower value. For these reasons, an interchange penalty of 10 minutes was selected.
- 3.2.12 A 30 minute allowance is also made for international check-in/customs. Table 6: Travel time weights and interchange penalty summarises the range of values referenced and the final selected values.

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Table 6: Travel time weights and interchange penalty

Service option	WebTAG guidance	Railplan	PLANET	Selected
In-vehicle time (factor)	1.0	1.0	1.0	1.0
Walking time (factor)	1.5 to 2.0	2.0	2.0	2.0
Waiting time (factor)	1.5 to 2.5	2.0	2.0	2.0
Interchange penalty	5 to 10 minutes	7.0	3.5	10.0
International check-in allowance	NA	NA	NA	30.0

3.2.13

Where more formal appraisal has previously been undertaken, notably for the rail and APM options, discounted benefits and operating costs have been provided as a PVB and PVC, giving the present value of the future streams of (some) costs and benefits. It should be noted that in the previous work undertaken, construction costs have generally been presented as an undiscounted 2011 value and are not included as part of the PVC.

Community impacts

3.2.14

We include high-level commentary about the potential impacts on local communities during the construction and operational phases.

Risks

3.2.15

We include risks specific to the HS2-HS1 link -associated with delivery or operations- in the appraisal template.

4 Review of potential HS2-HS1 link usage and benefits

4.1 Introduction

4.1.1 Previous assessments of rail options have proposed a number of potential service patterns for international and domestic services that could use an HS2-HS1 link. In order to support the appraisal of the wide range of options covered in this review, projections for the number of passengers using the link have been reviewed based on the latest available data and consolidated to form a consistent set of projections.

4.1.2 Passenger projections are made up of three components:

- international passengers (who would use a rail link if provided, or transfer between Euston and St Pancras);
- domestic passengers (who would use a rail link if provided); and
- local travellers between Euston and St Pancras (who would use a local link if provided).

4.1.3 From this analysis, a maximum benefit has been identified for each of the rail infrastructure options. This is based on the benefits achievable, given service frequencies and connectivity.

4.2 Usage of international rail services

4.2.1 HS2 Ltd has reviewed the usage of international services to assess the likely patronage for a range of international service pattern options. It has considered the following options:

- international services from Old Oak Common
- international services from Birmingham
- international services from north of Birmingham
- international services from north of Birmingham (services split and join at Birmingham).

4.2.2 TfL has presented alternative demand projections in HS2-HS1 link: Technical and strategic case for a robust solution, and Greengauge 21's own projections are presented in Travel market demand and the HS1-HS2 link.

4.2.3 A summary of the forecasts available is shown in Table 7: International service demand forecasts. The range of projections vary approximately fourfold between the TfL projections at the lower bound and the Greengauge 21 projections at the upper bound.

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Table 7: International service demand forecasts

Annual demand (one-way)	Daily demand (one-way)	AM peak demand (one-way)	Source	Service assumption
0.95 million	2,600	650	TfL	Not specified
1.44 million	3,900	983	HS2 Ltd (12/2013)	0.5tph International services from Old Oak Common
1.89 million	5,200	1,299	HS2 Ltd (03/2014)	0.5tph International services from north of Birmingham, services split and join at Birmingham
3.98 million	10,900	2,700	Greengauge 21	Not specified ¹⁹

4.3 Benefits of international rail services

- 4.3.1 Considerably fewer data are available on the potential benefits of international rail services. HS2 Ltd's analysis of international rail services assesses the likely demand for services, the PVB, and the PVC comprising revenue, operational cost (OPEX) and rolling stock costs but excluding construction costs. On this basis, it identifies a six train per day service (with services splitting and joining at Birmingham) as offering the highest net present value (NPV). For options not requiring train paths north of Old Oak Common (OOC) -trains starting or terminating at OOC- it identifies a six train per day (0.5tph) service from OOC as offering the highest user benefits. However, while the user benefits of this option are substantial, the impact on OPEX means that the PVC exceed the PVB.
- 4.3.2 This analysis is sensitive to a number of assumptions, including ticket prices and track access charges. No financial appraisal is presented in the Greengauge 21 analysis. The TfL analysis includes some commentary on the financial benefits of the HS2-HS1 link but the inclusions/exclusions assumed and the level of benefits attributable to international services are unclear.
- 4.3.3 Therefore, HS2 Ltd's analysis forms the basis for discussion of the benefits of international rail services. Table 8: HS2 Ltd international services benefits appraisal identifies international services from north of Birmingham, with services splitting and joining at Birmingham, as the preferred option for international rail services.

¹⁹ Forecast includes passengers using domestic services via the HS2-HS1 link to access international services.

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Table 8: HS2 Ltd international services benefits appraisal

Annual demand (one-way)	PVB minus PVC	Source	Service assumption	Notes
1.44 million	-£250m	HS2 Ltd (12/2013)	0.5tph International services from Old Oak Common	PVC>PVB Requires international facilities at OOC
1.89 million	£677m	HS2 Ltd (03/2014)	0.5tph International services from north of Birmingham, services split and join at Birmingham	Assumes use of Heathrow paths. Requires international facilities at OOC, Birmingham Curzon Street, Birmingham Interchange, Manchester Piccadilly and Leeds New Lane

4.4 Usage levels for domestic rail services

4.4.1 In addition to international connections, the HS2-HS1 link offers opportunities for enhancing domestic services. Options for this have been assessed in a number of studies, giving a wide range of demand projections.

4.4.2 HS2 Ltd's recent analysis of these opportunities has used the PLANET framework Model. The central scenario assessed a two trains per hour domestic (Javelin equivalent) service running between Ashford and OOC, also exploring higher frequencies. Table 9: Domestic service demand forecasts sets out the forecast demand.

Table 9: Domestic service demand forecasts

Annual demand (one-way)	Daily demand (one-way)	AM peak demand (one-way)	Source	Service assumption
6.5 million	17,900	6,000	TfL	Not specified > 5tph required in peaks to support demand ²⁰
1.3 million	3,600	1,500	HS2 Ltd (03/2014)	2tph ²¹ Javelin services from OOC to Kent
15.9 million	43,500	14,500	Greengauge 21	Not specified ^{22 23} >26tph required to support demand ²⁴

²⁰ On the basis of a 550 passenger capacity service.

²¹ 4tph sensitivity test run in preliminary assessment – not progressed to final reporting due to reductions in NPV and exceeding technical capacity of the link.

²² Assumes provision of WCML connection to Crossrail 1 at OOC.

²³ Assumes direct connection from HS1 to Heathrow available.

²⁴ On the basis of a 550 passenger capacity service.

4.5 Benefits of domestic rail services

- 4.5.1 As in the analysis of international demand, HS2 Ltd's analysis included an appraisal of the costs and benefits (excluding construction) of proposed domestic services. The difference between the PVB (user benefits plus revenue) and PVC (OPEX plus rolling stock costs), was £250 million, as shown in Table 10: Domestic services benefits appraisal. The sensitivity testing indicates that a higher frequency (4tph) service attracts higher usage. However, this reduces the value of the benefits, as increases in benefits are more than offset by increases in operational costs.
- 4.5.2 Neither the Greengauge 21 nor the TfL study provides an economic appraisal of domestic services, but both forecast substantially higher flows than in HS2 Ltd's assessment. Both forecast that increases in demand will influence the optimum level of service provision.
- 4.5.3 In recognition of this, in the context of a higher demand scenario it is considered likely that domestic service frequencies above 2tph could offer additional benefits above the corresponding increase in costs. This should be considered when reviewing rail options capable of offering service capacities above 3tph.
- 4.5.4 It is not possible to quantify the level of benefits which this might achieve on the basis of the evidence currently available.

Table 10: Domestic services benefits appraisal

Annual demand (one-way)	PVB minus PVC £m	Source	Service assumption	Notes
1.3 million	£250	HS2 Ltd (03/ 2014)	2tph, Javelin	
>1.3 million	<£250	HS2 Ltd (03/ 2014)	4tph, Javelin	Full details not available
NA	>£250	Various	>2tph	Potential additional benefits from increased service frequency in a higher demand scenario

4.6 Total rail link demand

- 4.6.1 Total expected usage for the HS2-HS1 rail link at different levels of capacity is shown in Table 11: Rail link demand, annual and AM peak period. This identifies a peak three hour flow of around 2,800 passengers (in the peak direction) for links that meet the original specification of a 3tph capacity. Of these, approximately half would be international travellers. Lower-capacity links are assumed to be used by international services only.
- 4.6.2 The higher-capacity link options would enable a higher service frequency to operate on the link. In this scenario, the constraint on service volumes would be the availability of train paths on the HS1 and HS2 trunk routes.
- 4.6.3 While TfL's analysis identified a demand level equivalent to a 5tph domestic service, HS2 Ltd's analysis identified higher service levels as having a reduced net benefit. As discussed above, on this basis a higher-capacity link is judged to offer the opportunity for generating higher flows, but these are not quantified.

- 4.6.4 A key assumption underpinning the forecasts is that the proposed services call at Stratford International. As discussed in section 5, a number of the longer-distance tunnelled rail links bypass Stratford and so do not provide this functionality.
- 4.6.5 Whilst no analysis has been undertaken to assess the impact of this connection being unavailable the reduced connectivity to East London would be expected to reduce usage and benefits for these options.

Table 11: Rail link demand, annual and AM peak period

Rail link capacity	Assumed service pattern	Annual usage (one-way flows)	AM peak (one-way flows)
<3tph	International services from Birmingham Interchange, 6 trains per day	1.9 million	1,300
3tph	International services from Birmingham Interchange, 6 trains per day	1.9 million	1,300
	Domestic services from OOC to Ashford, 2tph	1.3 million	1,500 ²⁵
>3tph	International services from Birmingham Interchange, 6 trains per day	1.9 million	1,300
	Domestic services from OOC to Ashford, 2tph	1.3 million	1,500
	Additional domestic services, various	TBC	TBC

4.7 Total rail link benefits

- 4.7.1 Based on the demand and benefit projections set out above, the potential benefits of an HS2-HS1 link with differing levels of capacity has been assessed. The results are shown below.
- 4.7.2 As already identified, HS2 Ltd's analysis is the primary source for appraising the benefits of the proposed services. It evaluates the user benefits, revenue impacts, OPEX and rolling stock costs of the options proposed. The central case evaluation of these is shown in Table 12: Total rail link benefits.
- 4.7.3 The benefits do not include any allowances for wider economic benefits, such as agglomeration or imperfect competition. It should also be noted that this analysis is highly sensitive to the supporting assumptions.

²⁵ Domestic services have lower annual but higher peak flows due to commuter peaks.

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Table 12: Total rail link benefits

Rail link capacity	Service group	Benefits	Revenue	OPEX	Rolling stock	PVB	PVC
<3tph	International	£825	£1,690	£1,640	£197	£2,515	£1,837
3tph	International	£825	£1,690	£1,640	£197	£2,515	£1,837
	Domestic	£864	£730	£1,310	£35	£1,594	£1,629
>3tph	International	£825	£1,690	£1,640	£197	£2,515	£1,837
	Domestic	£864	£730	£1,310	£35	£1,594	£1,629
	Additional domestic	£TBC				£TBC	£TBC

4.7.5 For international services, HS2 Ltd has explored variation in fares and track access charge assumptions. It shows that the Net Present Value (NPV) of benefits for international services could vary by +/- £800 million.

4.7.6 Service frequency is a key variable in assessing the benefits of domestic services. HS2 Ltd considers that increasing service frequencies above 2tph reduces the NPV of domestic services, as increased revenue and benefit gains are outweighed by increases in operating costs. We recommend that, in light of the higher projections in other studies, rail links with a capacity to run more than 3tph are identified as capable of achieving higher benefits.

4.8 Local demand for non-rail links

4.8.1 We have reviewed a number of data sources gauging potential usage for non-rail options between Euston and St Pancras. Potential users fall into one of three categories:

- local area background walking movements;
- local area background public transport movements; and
- international transfer passengers.

4.8.2 Pedestrian movement projections for the Euston Station area were developed as part of the hybrid Bill's Environmental Statement, to assess local pedestrian comfort levels for the hybrid Bill design proposals and reflect forecast numbers for 2041.

4.8.3 There are limited data on local public transport trips between Euston and St Pancras. TfL's Rolling Origin Destination surveys (RODs) indicates two-way London Underground flows between the stations of around 400 in the morning peak period and 1,850 in the evening peak period. Assuming that one-way flows are 50% of these totals suggests a range of 200-900 passengers. Allowing for bus passengers suggests a range of perhaps 500-1,000 passengers.

4.8.4 The projected volume of international transfer passengers is based on the HS2 Ltd International demand forecasting and appraisal report of February 2014. This does not fully define whether international rail travellers use high speed or conventional rail to access international services on HS1. A range of values was estimated for this market based on a 2036 forecast year.

- 4.8.5 The lower bound reflects the additional annual international rail trips generated by the introduction of the HS2 network (i.e. only the incrementally generated trips are assumed to use HS2 to access London), the upper bound of the range reflects all the international rail trips from areas outside London but served by HS2 in the HS2 no link scenario (i.e. all international travellers who have the opportunity to use HS2 to access London).
- 4.8.6 Together, these three values make up the potential market for the journey between Euston and St Pancras. Given the lack of detail available, our approach assumed that up to 50% of the existing local walk movements would transfer to an APM system and up to 33% of existing local walk movements would transfer to an enhanced walking route.
- 4.8.7 Table 13: Local demand annual and AM peak period indicates that the potential local walk market is significantly larger than either the local public transport market or international transfers expected without a rail link between HS2 and HS1 in place. The local walk movement represents a wide range of specific origins and destinations, which makes identifying potential uptake from this group less certain and any local infrastructure would only capture a proportion of local users. Given the lack of detail available, our approach assumed that up to 50% of the existing local walk movements would transfer to an APM system and up to a 33% of existing local walk movements would transfer to an enhanced walking route.

Table 13: Local demand annual and AM peak period

Market	Description	Annual usage ²⁶ (one-way flows)	AM peak (one-way flows)
Local walk	Walking journeys from the Euston area towards St Pancras station	8.5 million	6,000
Local public transport	Bus and Underground journeys from Euston to St Pancras station	Min 0.72 million Max 1.43 million	500-1,000
International transfer	Projected international rail travellers using HS2 to access London	Min 0.35 million Max 1.15 million	250 – 800

- 4.8.8 Each non-rail option has been assessed as attracting a proportion of the various markets available, this is based on location, GJT (including any fares component) and whether the option is assumed to be available to non-international travellers. Given their faster journey times, APM-based options are considered to attract a greater proportion of local travellers. A significant proportion of local users would, however, continue to use existing modes or routes.
- 4.8.9 Total demand by option family is set out in Table 14: Demand by option family.

²⁶ Estimated from annualisation factors for international trips.

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Table 14: Demand by option family

Option family	Potential passenger demand 0700-1000			
	International rail usage	Domestic rail usage	Local usage	Total usage
Existing modes via Euston-St Pancras	250-800	NA	7,000	7,250-7,800
Rail options via OOC	1,300	1,500	NA	2,800
APM options via Euston-St Pancras	250-800	NA	3,000 ²⁷	3,250-3,800
Enhanced walk options via Euston-St Pancras	250-800	NA	2,000 ²⁸	2,250-2,800

4.9 Opportunity costs

- 4.9.1 Consideration of the benefits of domestic and international services is also required in scenarios which result in reduced capacity for other services. This 'opportunity cost' issue has important implications for two major issues.
- 4.9.2 The first issue is the running of international services on the trunk (north of OOC) HS2 route, where at periods of peak demand there is likely to be competition for train paths between domestic and international services.
- 4.9.3 Initial consideration of this issue in High Speed Rail - London to the West Midlands and beyond Supplementary Report of September 2010 concluded that, at peak times, the high loadings of domestic HS2 services to London would restrict opportunities for international services to run north of OOC, with the domestic services having priority. However, the latest analysis by HS2 Ltd shows very high load factors for the preferred international service proposal. On this basis, the projected NPV was considered to be achievable. It should be noted that the benefits of additional domestic services has not been assessed and could offer higher benefits. This would restrict the paths available for international services to non-peak periods, thereby reducing the benefits achievable.
- 4.9.4 The second issue is the potential disbenefits of link options that affect the capability of existing rail infrastructure such as the NLL. This issue informs discussion of the operational impacts of various rail options and is a key stakeholder concern.

²⁷ The remainder of the local travellers continue to use their existing mode/route. Given the lack of detail available about the precise origin and destination of flows between Euston and St Pancras, our approach assumed that up to 50% of the existing local walk movements would transfer to an APM system.

²⁸ Given the lack of detail available about the precise origin and destination of flows between Euston and St Pancras, our approach assumed that up to 33% of existing local walk movements would transfer to an enhanced walking route.

5 Baseline comparator

5.1 Existing and committed connections

- 5.1.1 Understanding the connections that would be available between the existing HS1 terminus at St Pancras and the planned Euston terminus for the HS2 route is important as it reflects the baseline comparator against which options have been assessed. The full range of routes, including those not currently existing but available in future, include:
- walk between Euston and St Pancras;
 - London Underground/bus between Euston and St Pancras;
 - taxi between Euston and St Pancras; and
 - Crossrail 1 between Old Oak Common and Stratford.
- 5.1.2 These routes are summarised in Table 15: GJT for baseline comparator travel options, along with key journey characteristics that have been used to estimate a generalised journey time (GJT) for each option, between two points common to all options (Old Oak Common and Stratford). In line with UK government appraisal guidance (WebTAG), this identifies the perceived costs of the options for international travellers transferring between the two stations.
- 5.1.3 The GJT for all three local interchange options are highly comparable, but this analysis does not include allowance for the fares for each options. This would impact strongly on taxi and, to a lesser extent, public transport options.
- 5.1.4 Whilst travel card users may be expected to use a mix of walking and public transport modes, use of walking routes to interchange between the two stations is considered the most likely outcome in the baseline comparator scenario.

Table 15: GJT for baseline comparator travel options

Connection type	Description	Generalised Journey Time (GJT) ^{29,30}
Walk between Euston and St Pancras	Walking routes between Euston and St Pancras via Euston Road and Phoenix road	141
London Underground/bus between Euston and St Pancras	Bus and Underground services between Euston and St Pancras station	137
Crossrail 1 between Old Oak Common and Stratford	Crossrail 1 services between Old Oak Common and Stratford	168
Taxi	Taxi services	136

²⁹ Perceived cost of travelling between OOC and Stratford via Euston-St Pancras, expressed in minutes and detailed in Appendix D.

³⁰ Fares (public transport and taxi) not included.

5.1.5 These generalised times are set out in Appendix D and indicate that, over this comparable section, existing connections offer a GJT of 136 to 168 minutes between Old Oak Common and Stratford. This presents a baseline cost estimate for evaluating the potential benefits of rail, APM and travelator, and other options.

5.1.6 A number of walking routes exist between Euston and St Pancras. Routes along Euston Road or Phoenix Road provide the shortest journey times at just under 10 minutes between the two stations. These are shown in Figure 7: Indicative walking routes. A 'Euston Road problem', associated with the perceived inadequacy of the available walking links between the two stations, has been raised by a number of parties.

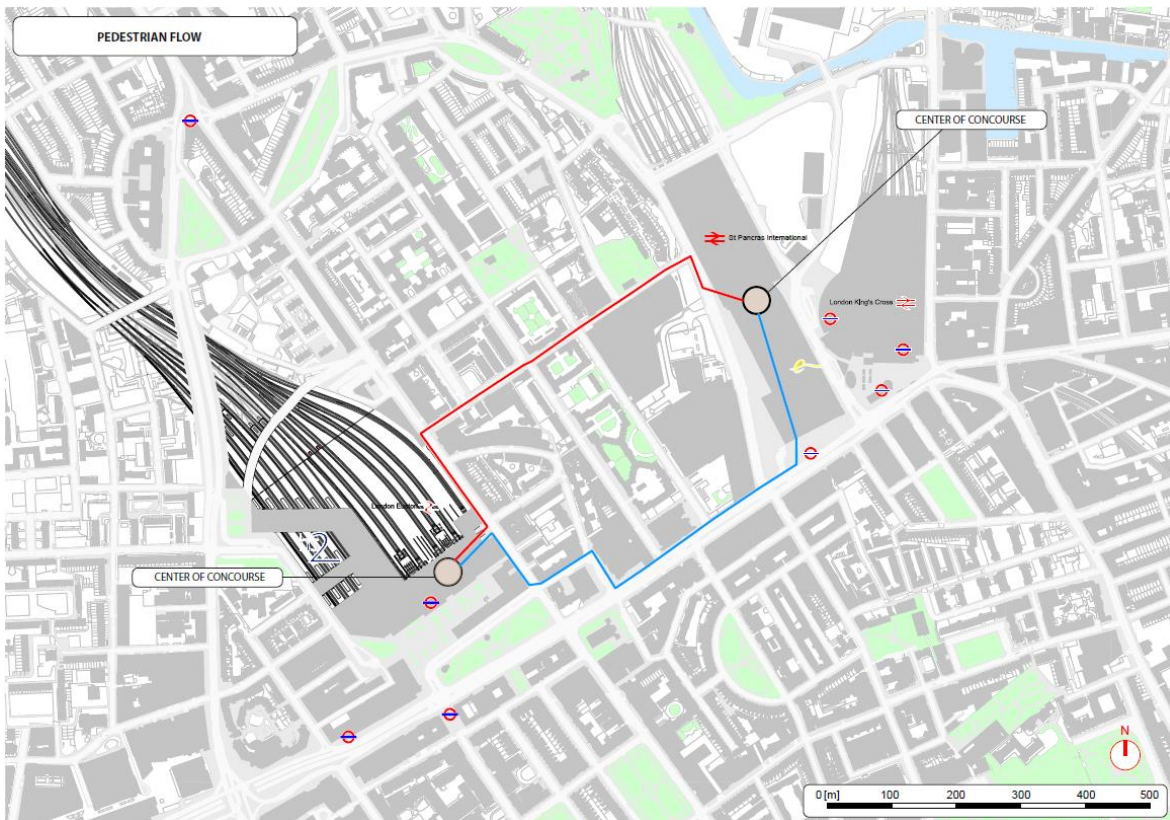


Figure 7: Indicative walking routes

5.1.7 There are numerous local public transport connections between the two stations, with the Northern and Victoria lines providing high frequency connections from Euston, and Metropolitan, Hammersmith & City and Circle line services running from nearby Euston Square station; these are shown in Figure 8: Indicative public transport connection, London Underground. Multiple bus routes link the two stations along the route shown in Figure 9: Indicative public transport connection, Bus. Taxi use would also be an option, particularly for travellers with baggage. The taxi route is shown in Figure 10: Indicative public transport connection, Taxi.

5.1.8 The option of connecting between HS2 and HS1 by using Crossrail 1 to transfer between Old Oak Common and Stratford International is not currently available but would be in place on

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opening of HS2 Phase One. This would provide a high frequency (12tph) across- London connection with a 25 minute journey time. There would be a need to change onto the DLR to travel between Stratford Regional and Stratford International stations, so as to interface with HS1 at Stratford. The viability of this option would be dependent on the implementation of immigration and customs controls at Stratford International station to allow international services to call here. An alternative would be to use HS1 domestic services between Stratford International and Ebbfleet where immigration and customs control facilities are available.

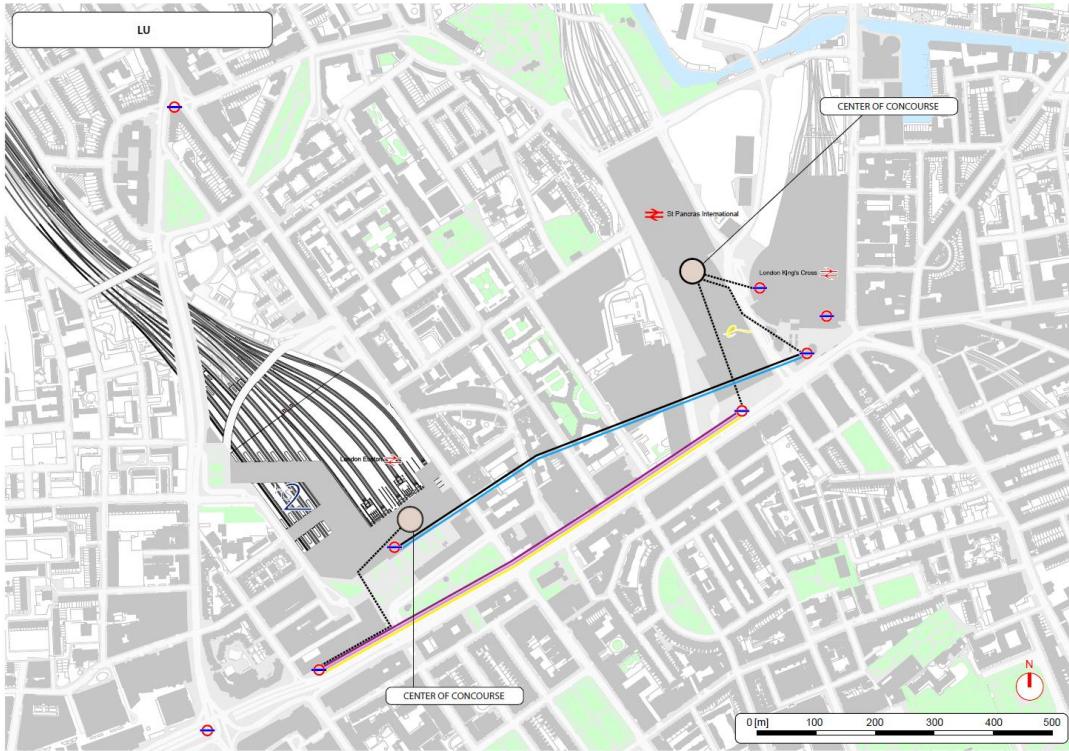


Figure 8: Indicative public transport connection, London Underground

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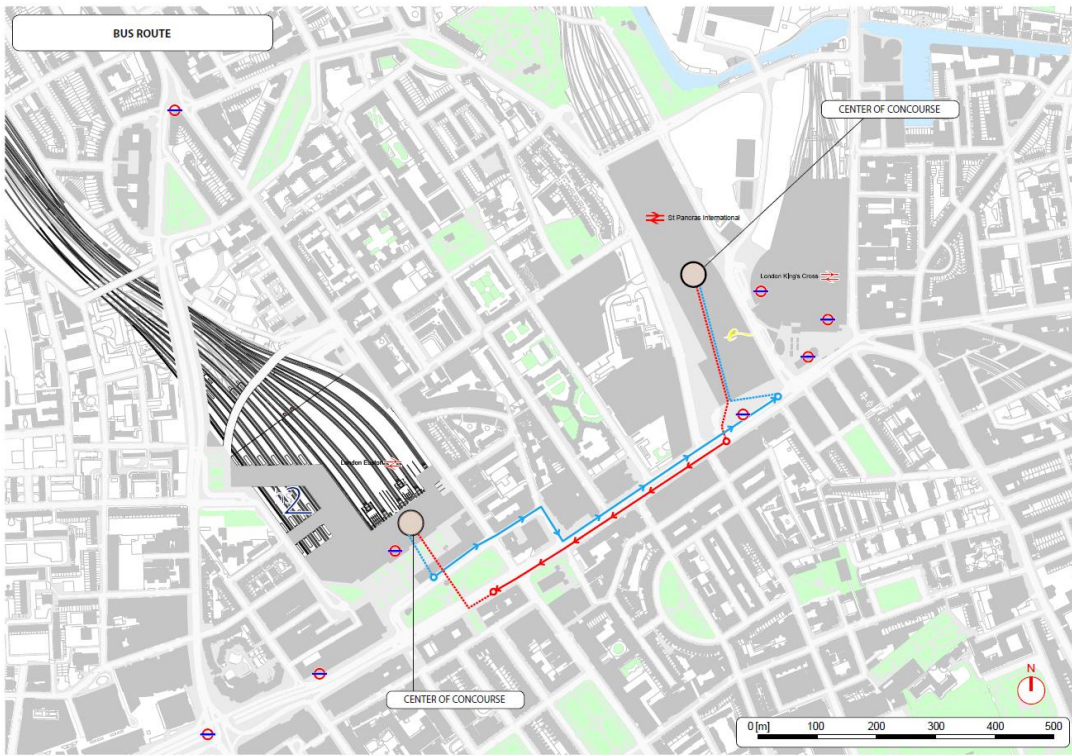


Figure 9: Indicative public transport connection, Bus

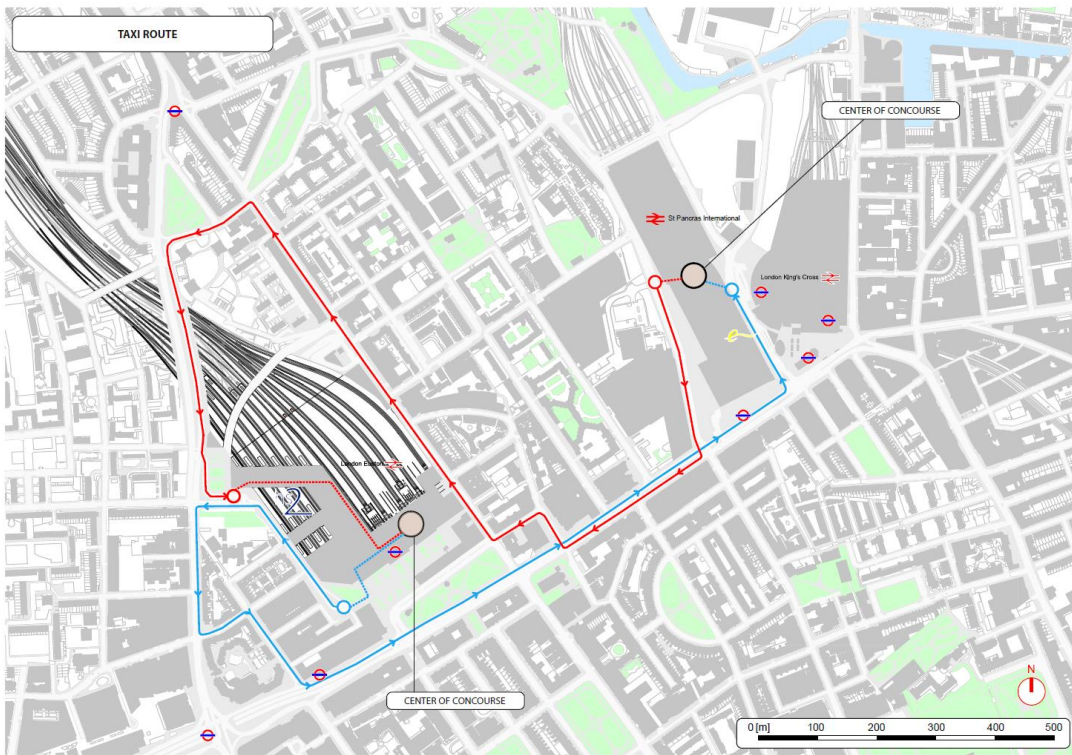


Figure 10: Indicative public transport connection, Taxi

5.2 Impact on local community

- 5.2.1 Up to 800 international travellers might use these existing routes over the morning peak period from 0700-1000. The impact of this increased usage is considered to be relatively small. In this context, the impact on the local community of increased levels of walking would be strongly dependent on the routes used.
- 5.2.2 Euston Road between Euston and St Pancras is largely commercial, and already experiences high traffic and footfall levels. Increased pedestrian use of this road would not change the character of the area but could increase pedestrian congestion levels.
- 5.2.3 Phoenix Road is a primarily residential area, with limited footfall and traffic. A significant increase in footfall might require a greater orientation to public realm and local business uses and would need to be sensitively managed.

5.3 Risks

- 5.3.1 We have presented a public transport route between OOC and Stratford via Crossrail 1 as an option, but the potential for international passengers to use this would depend on the future usage of Stratford International station by international services.

6 Assessing enhanced walk options at Euston

6.1 Introduction

- 6.1.1 We have reviewed the options for enhancing the walk connections between Euston and St Pancras. This identified two sets of potential option 'families' as set out in Table 16: Enhanced walk option families at Euston.

Table 16: Enhanced walk option families at Euston

Option 'family'	Description
Enhanced street level walking route	Options for improved pedestrian infrastructure between Euston and St Pancras.
Use of Crossrail 2 station as a walking route	Options for use of the proposed Crossrail 2 station as a subsurface walking route.

6.2 Enhanced street level walking route

- 6.2.1 The objective of these enhanced street level walk options is to improve the quality of the walking connections between Euston and St Pancras. We recognise that providing a comfortable and safe pedestrianised route would not result in savings in GJT.

Route

- 6.2.2 Analysis of the existing walking routes, as set out in section 5.1, identifies that walking routes via Phoenix Road and Euston Road offer the shortest journey distances and times. While other routes are possible, for example via Polygon Road or Brill Place, these are more complex from a wayfinding perspective, and do not offer the opportunity of a direct visual connection between the stations.
- 6.2.3 The route via Euston Road is currently the more prominent of the two routes. However, the high levels of vehicle and pedestrian traffic would limit the achievable environmental quality.
- 6.2.4 The preferred option for delivering a high-quality walking environment would be to connect between Euston station and St Pancras International by walking at street level along Phoenix Road. The option would require landscaping on Phoenix Road and improvements to the streetscape to create an attractive walking route between the stations.
- 6.2.5 To maximise the benefits of this route, any provision would also need to be fully integrated with signage and other wayfinding measures at Euston and St Pancras stations. This would communicate the availability of the route and support its uptake in preference to the Euston Road route, which is currently more prominent.
- 6.2.6 Including elements of street-level travelator provision could be considered within this scheme, but this would raise issues of local severance and would have limited journey time benefits. Enhanced street level walking routes could be supported by taxi use for mobility-impaired

passengers or, potentially, a shuttle bus service, although this has not been investigated at this stage.

Link operational capacity

- 6.2.7 A pedestrian walking route would need sufficient capacity to accommodate predicted passengers at an appropriate level of comfort. The design would need to reflect usage by international rail passengers and existing local walking patterns.

Impact to local community

- 6.2.8 Impacts to the local community could arise through the increase in local footfall. Maximising the benefits to the local community from this change would require sensitive implementation.

Costs

- 6.2.9 Costs for a proposal of this type would be lower than either the rail or APM-based options. Analysis in 2010 identified costs of £2.25 million (Table 17: Construction costs for enhanced street level walking routes) for an enhanced street-level walk. This cost projection is highly dependent on the extent of intervention required, so further development of this proposal would be required to confirm a robust cost.

Table 17: Construction costs for enhanced street level walking routes

Option family	Cost
Enhanced street level walking route	£2.25 million

Benefits

- 6.2.10 Journey times for this option would remain the same as in the baseline comparator but the look and feel of the route would be substantially improved. Hard and soft landscaping measures could be used to help integrate the route within the existing urban fabric, supporting a more commercial and public realm orientation of the area without negative impacts on existing residential usage.

6.3 Sub-surface route using Crossrail 2

- 6.3.1 As part of the Crossrail 2 proposals under development, a new Euston/St Pancras station would be provided with station entrances connecting with St Pancras to the east and Euston to the west. This station connection could form an additional sub-surface walking route between the two stations (Figure 11: Sub-surface route via Crossrail 2).
- 6.3.2 The walking distance for this in-station walking route would be comparable to the existing street level routes. It would involve a number of level changes and entry/exit through revenue protection areas, but could have benefits for some users. It would be weather-protected and could feature a high level of mechanical assistance (ie, escalators and travelators).

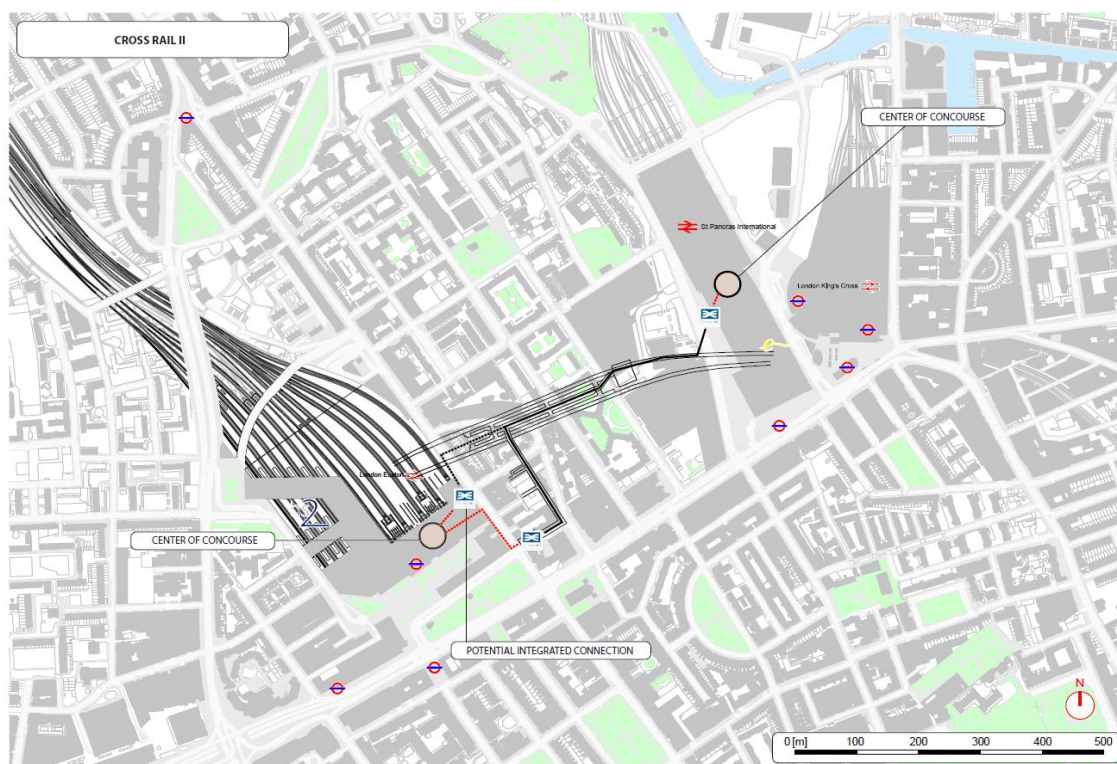


Figure 11: Sub-surface route via Crossrail 2

Rail operation impact

6.3.3 As currently conceived, the Crossrail 2 proposals have not been developed to facilitate through-movements of this type. Discussions with TfL about the interchange between Euston and St Pancras indicate that they would prefer any between-station movements of this type to be managed outside of the station.

6.3.4 Some passengers may become aware of this opportunity but it is unlikely to be supported by TfL signage.

Impact to local community

6.3.5 This option would have minimal impacts on the local community.

Costs

6.3.6 This option assumes delivery of Crossrail 2 as currently proposed, and no allowance has been made for design changes to facilitate this movement.

Benefits

6.3.7 A journey time assessment of this route has been undertaken that indicates a potential journey time saving. However, accessing this route would require passengers to enter the LU/Crossrail 2 station, which would be revenue-protected.

6.3.8 It is considered that travellers with travel cards or similar would be more likely to use LU services, which offer further reductions in GJT.

7 Assessment of rail options

7.1 Rail option families

7.1.1 The large number of rail link options proposed have been grouped into broad families, so as to compare the options more easily. The families are set out in Figure 12: HS1-HS2 rail link options family - definition and are reviewed in the following sections.

7.1.2 Two different themes can be identified within the options:

- rail links that run across the Camden area – Rail Options Central
- rail links that avoid the Camden area – Rail Options Eastern.

7.1.3 These can be differentiated by the physical infrastructure proposed for each option, namely:

- rail links that, after a tunnelled section from Old Oak Common Station to the Camden area, continue at surface through an existing rail corridor on shared or segregated tracks; and
- rail links that use dedicated, fully tunnelled routes to link HS2 services to HS1 lines.

7.1.4 An analysis of the rail link options shows the following:

- Fully tunnelled options were mainly developed to avoid impacts on existing rail operations and on the community of Camden, during construction and operation, but these raise cost-benefit issues owing to the cost of long underground construction.
- Rail links via Camden, using largely existing infrastructure on shared tracks, try to bring better value, but do so at increased level of impact.
- Options for segregated HS2 and existing rail services via Camden try to minimise rail operations conflicts at controlled costs, but still result in permanent impact on the local community, as well as temporary disruption during construction.

7.1.5 Petitions have identified a number of additional alternative rail options and these are considered later in the report. These largely form variants to the previously identified family groups.

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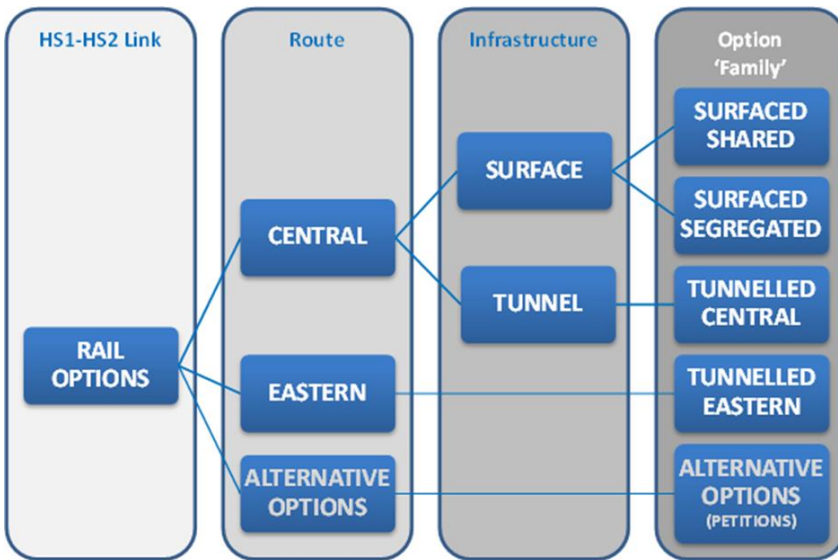


Figure 12: HS1-HS2 rail link options family - definition

7.1.6 The broad description of each rail link option family is set out in Table 18: HS2-HS1 link rail option families scope - description, along with the relevant link option layout reference.

Table 18: HS2-HS1 link rail option families scope - description

Option family	Description	Layout reference
Rail Options Central	Rail link options that use tunnelled sections from Old Oak Common Station to Camden area, then existing railway corridors with shared use of rail lines	Option RB; Option R0; and Option R4C.
	Rail link options that use tunnelled sections from Old Oak Common Station to Camden area, then existing railway corridors with segregated rail lines.	Option R2; Option R2A; Option R2B; Option R4A; and Option R4B.
	Rail link options that use dedicated (segregated) tunnelled rail lines, between Old Oak Common Station and Camden.	Option R1A; Option R1B; Option R1C; Option R3; Option R5; and Option R6.
Rail Options Eastern	Rail link options that use dedicated (segregated) tunnelled rail lines, longer distance rail tunnels between Old Oak Common and Stratford or beyond.	Option RA; Option R7; and Option R8.

7.1.7 Figure 13 illustrates the existing rail layout as well as identifying the main rail services around the Camden area.

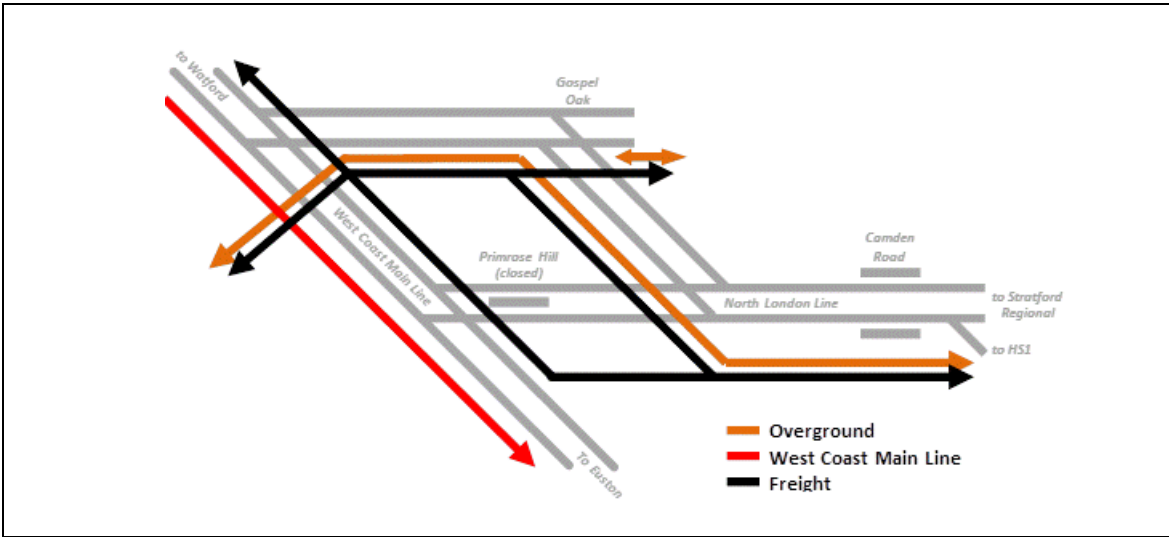


Figure 13: Existing track layout and existing main rail services

7.1.8 Figure 14: Rail tunnel plus shared surface operation - track diagram, illustrates the typical rail layout proposed within the Rail Options Central options (rail tunnel plus shared surface operation). Starting as a tunnel from Old Oak Common station, the routes continue along an existing rail corridor using the same tracks as existing rail services.

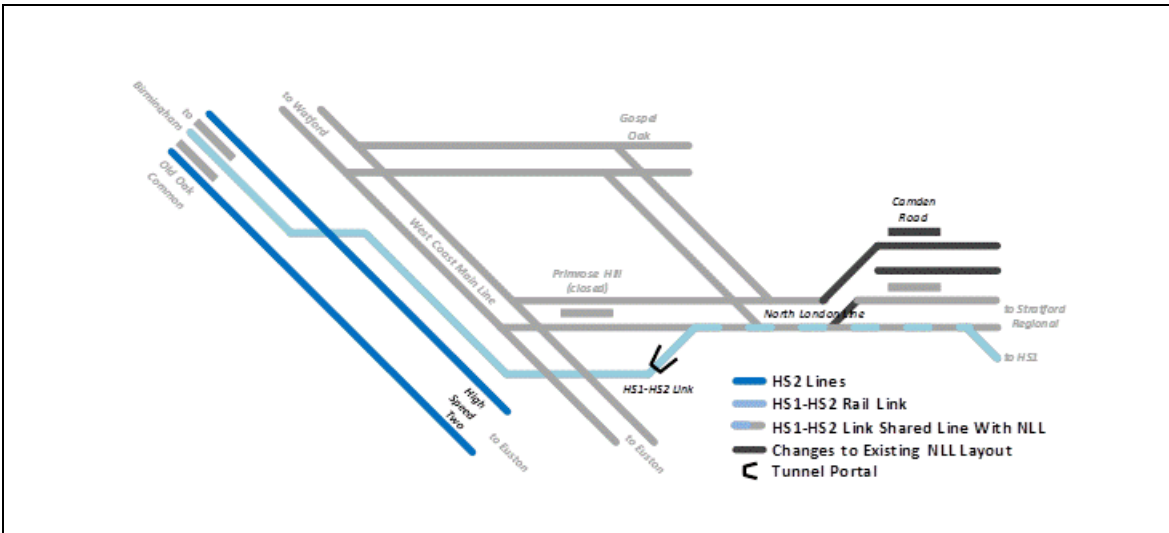


Figure 14: Rail tunnel plus shared surface operation - track diagram

7.1.9 Figure 15: Rail tunnel plus segregated surface operation - track diagram, illustrates the typical rail layout proposed within the Rail Options Central options. Starting as a tunnel from Old Oak Common station, the routes continue through an existing rail corridor - but using dedicated HS1-HS2 tracks.

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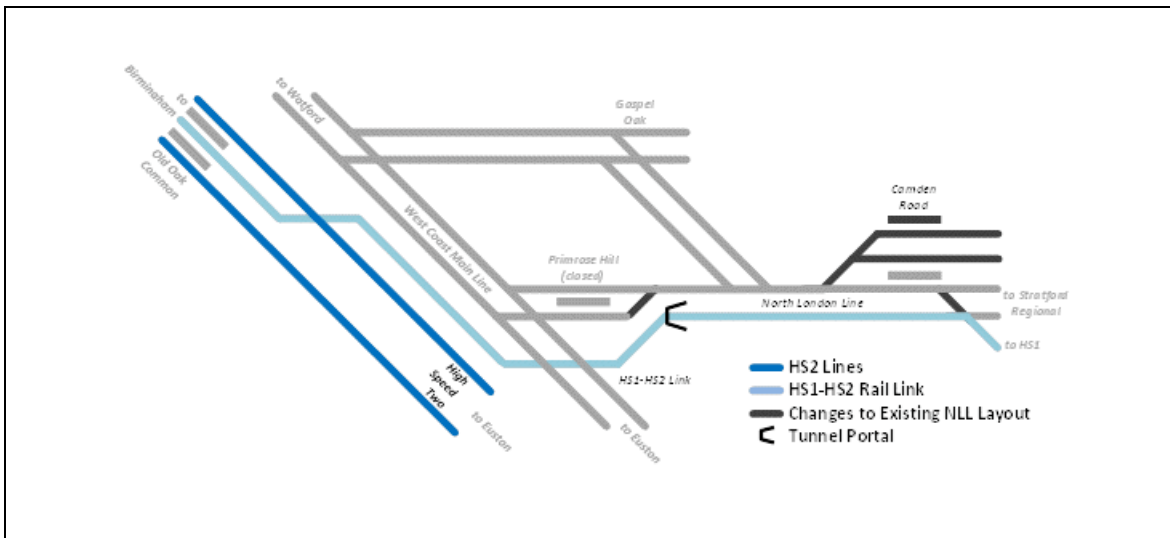


Figure 15: Rail tunnel plus segregated surface operation - track diagram

7.1.10 Figure 16: Rail tunnel between Old Oak Common and Camden - track diagram illustrates the typical rail layout proposed within the Rail Options Central options (rail tunnel between Old Oak Common and Camden). Starting as a tunnel from Old Oak Common station, the routes rise to the surface somewhere in the Camden area before linking to the HS1 service via new tracks.

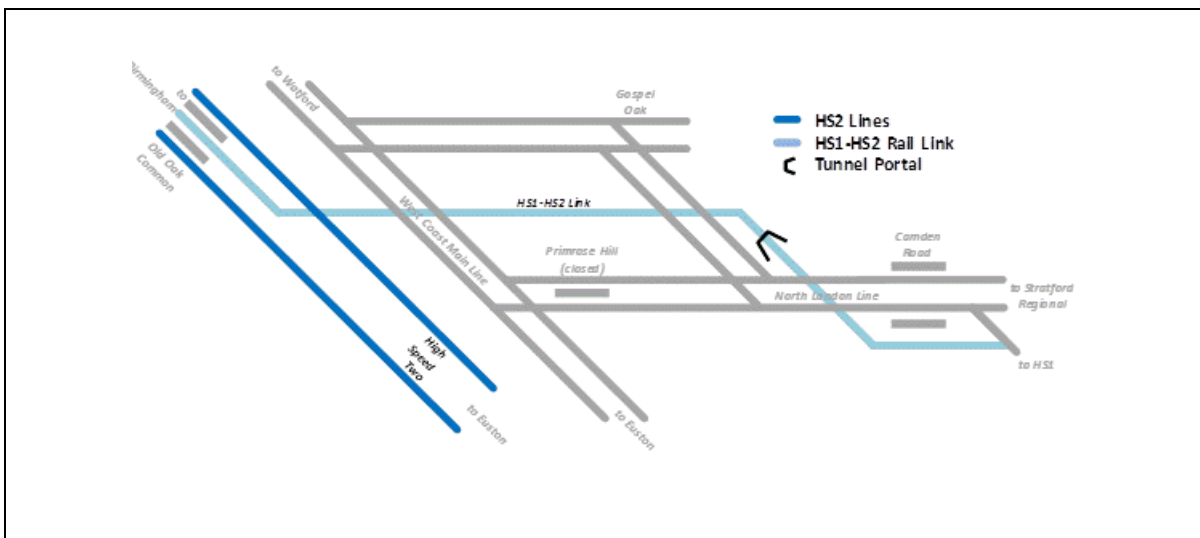


Figure 16: Rail tunnel between Old Oak Common and Camden - track diagram

7.1.11 Figure 17: Longer distance rail tunnel between Old Oak Common and Stratford or beyond - track diagram, illustrates the typical rail layout proposed within the Rail Options Eastern options. In general, these start from the HS2 tunnels and link to HS1 lines east of Stratford International Station. These are long rail tunnel options, avoiding the busy Camden area.

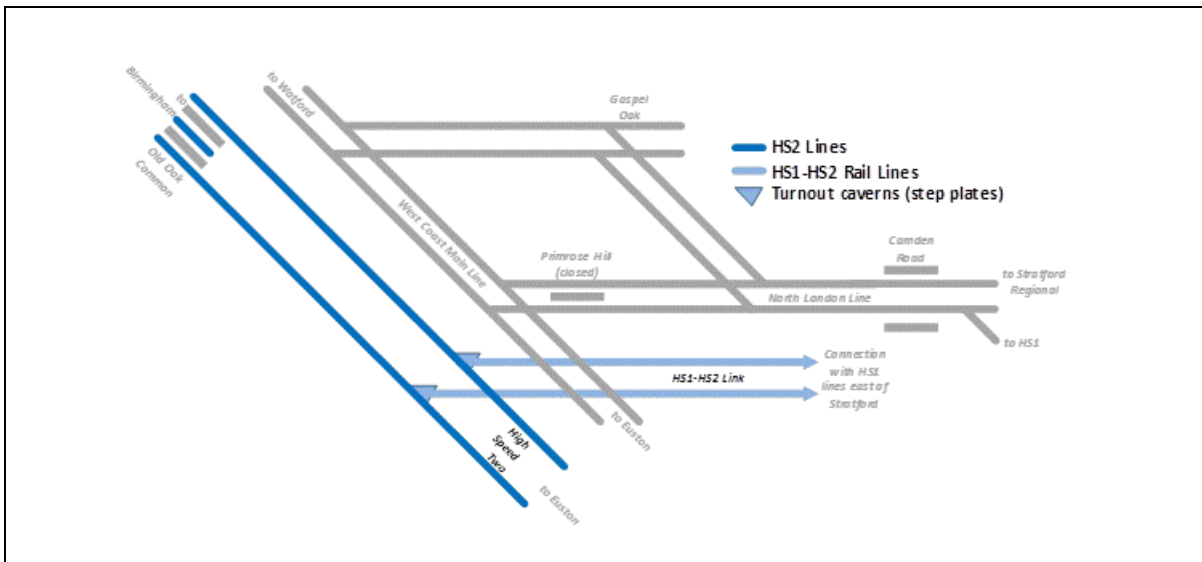


Figure 17: Longer distance rail tunnel between Old Oak Common and Stratford or beyond - track diagram

7.1.12 Passive provision is considered separately in Section 7.6, with a summary of the selected adequate passive provision included in each rail option family section.

7.2 Rail tunnel plus shared surface operation

7.2.1 The rail tunnel plus shared surface operation family of options use existing railway corridors, with shared use of rail lines via Camden:

Rail tunnel plus shared surface operation options	Option RB
	Option Ro
	Option R4C

Route

7.2.2 These options start at Old Oak Common Station. They use a single bore tunnel going eastwards to a tunnel portal in the Camden area from Chalk Farm to Primrose Hill. Then they join the NLL, upgrading its southernmost track to GC gauge and using this corridor to connect to the HS1 link near St Pancras.

7.2.3 Initially, there was an exception to this typical route, which was an Option RB variant. This variant considered a shared double track rail link, using both of the NLL tracks. The option was abandoned, owing to the difficulty of taking both NLL tracks and the extensive works required to upgrade these same tracks to GC gauge.

Link operational capacity

7.2.4 In line with the Network Rail (NR) timetable capacity evaluation conclusions of July 2012, the rail link options that considered shared use of the NLL would not be able to meet the combined service requirements of HS2, TfL and NR. It is assumed that the rail surface shared

link options would not be able to meet the HS2 Sponsor's requirement of accommodating three high speed service trains per hour in each traffic direction without a significant reduction on TfL's and NR's passenger and freight services, in and around the NLL.

7.2.5 Rail surface shared link options do not allow any provision for future increases in HS2 services.

Rail operation impact

7.2.6 As noted above, shared use of the NLL south track would have a significant negative impact on existing rail operation. NR considers the rail surface shared link options to be operationally non-viable.

7.2.7 As well as affecting TfL's and NR's current operational capacity, an additional consequence would be that any rail tunnel plus shared surface options would limit future NLL expansion plans.

7.2.8 During construction, the rail tunnel plus shared surface options would also cause significant disruption to existing rail services, owing to the requirement for upgrading the shared track to GC gauge. As a consequence, this would require the widening/replacement of some of the existing structures along the NLL corridor such as viaducts and bridges. Works required for the track upgrade and structures widening and/or replacement would necessarily lead to major track possessions and current speed restrictions.

Impact to local community

7.2.9 These options involve the upgrade of existing tracks and structures, and so would have a limited permanent impact on local communities. According to an environmental assessment produced by HS2 consultants in May 2013, the level of permanent impacts caused by the rail tunnel plus shared surface options would be limited to the demolition of one residential, five commercial and two industrial properties.

7.2.10 During construction, this family of options would involve a high level of temporary disruption. Eleven roads would be severed temporarily as well as creating noise, vibration and dust emissions owing to some construction work around the affected existing structures. Construction work would include:

- reconstruction of Camden Lock and Camden Road bridges;
- modifications to south side of Randolph Street, Baynes Street and St Pancras Way bridges;
- widening of bridges at Kentish Town, Camden West Junction and at supermarket access;
- modifications to platforms and track layout at Camden Road Station; and
- remodelling of Camden West Junction.

Costs

- 7.2.11 Cost estimates presented for all rail tunnel plus shared surface options range from £580 million to £890 million. The lower figure represents Option o (PCR). Costs for all options were calculated at 2011 prices and are inclusive of all construction costs, indirect costs, efficiencies and risk allowances. Cost estimates exclude property purchase and potential compensation costs. A detailed breakdown of these costs by option, along with the source for all costs, is provided in Appendix C.

Benefits

- 7.2.12 These options provide a direct rail link between HS2 and HS1. When taking the environmental assessments into account, surface options tend to be favoured over tunnelled options owing to their more limited impacts on the local community and businesses. These options do not meet the HS2 Sponsor's requirement of 3tph capability. On this basis, it is assumed that rail services would be limited to the 6tpd international service with no domestic services possible. This would result in morning peak usage projection of around 1,300 passengers, one-way, with the service having a PVB of £2,515 million and a PVC (excluding construction costs) of £1,837 million. Based on internal DfT analysis, these options would not offer good value for money.

Risks

- 7.2.13 Previous studies address the impact of HS2 demand on existing conventional passenger and freight services with a shared link option, and how this would also impact on TfL's and NR's future expansion plans. In the event of increased demand for HS2 services beyond the established three trains per hour in each direction, there is a risk of increased impact, and therefore of increased conflict.
- 7.2.14 The shared link options would also require widening and refurbishing of existing structures, namely viaducts and rail bridges. The relatively unknown condition of these structures is considered to be a risk. Worse-than-expected conditions can lead to more extensive works and subsequent cost increases. Existing track upgrades and works on existing rail structures would require works in and around live tracks.

Passive provision

- 7.2.15 Adequate passive provision could be provided, allowing for a shared link option to be constructed at a later date (after Phase One).
- 7.2.16 A detailed description of the associated passive provision is presented in section 7.6, including its impacts on existing rail operations and local communities during the construction of passive provision and in the future, when the rail link option is completed.
- 7.2.17 Building a tunnel stub of around 450m long from Old Oak Common Station and allowing the necessary station layout to accommodate the future HS1-HS2 rail link track would mean that these options could be delivered at a later date, albeit with some additional impacts on local communities and costs, as detailed in section 7.6.

- 7.2.18 The estimated construction cost of the 450m tunnel stub from Old Oak Common is around £42 million (at 2011 prices). Alternatively, the cost of building the entire 6,290m length of the HS1-HS2 link tunnel would cost around £265 million (at 2011 prices).

7.3 Rail tunnel plus segregated surface operation

- 7.3.1 The rail tunnel plus segregated surface operation 'family' of options would use existing railway corridors via Camden, with segregated rail lines for the HS1 link. These options were developed to identify and address the operational constraints of the shared service track options. The five options reviewed are listed below:

Rail tunnel plus segregated surface operation options	Option R2
	Option R2A
	Option R2B
	Option R4A
	Option R4B

- 7.3.2 Option R2, known as the "NLL Enhanced", was initially developed and proposed by NR and was later presented as the HS1-HS2 connection in the HS2 London-West Midlands Environmental Statement, November 2013. This option family is based around Option R2, and its variants seek to reduce the impact on rail operations and on the local environment.

Route

- 7.3.3 The option route and its variants would start at Old Oak Common Station using a single bore tunnel eastwards to a tunnel portal in the Primrose Hill area. They would then join the NLL, making exclusive use of the upgraded NLL southernmost track, before connecting to the HS1 link near St Pancras.
- 7.3.4 In general, with the viaduct widening and bridge works between Camden Road West Junction and St Pancras Way, as well as some freight traffic diversions and alterations to Camden Road Station layout, the NLL south track would be used exclusively for HS2 trains.

Link operational capacity

- 7.3.5 These options consider one track dedicated to the HS1-HS2 link service and would therefore be capable of meeting the HS2 Sponsors' requirement of three high speed service trains per hour in each direction. This scenario would be achieved without permanently reducing the existing rail operation capacity of the NLL. These options would limit the potential for future provision of a second dedicated track for HS1-HS2 link services.

Rail operation impact

- 7.3.6 These options would provide a segregated line for HS2 services, mitigating the impacts on the current NLL passenger and freight capacity. However, they would limit future NLL expansion

plans by taking up one of the two available tracks and the necessary space for any potential increase to the number of NLL tracks.

- 7.3.7 As with the shared track options, these options would cause substantial disruption to existing rail services during construction, as a consequence of the need for NLL south track upgrading. In the same way, owing to the need to remodel the station/junction operational layout and provide new main line connections, a large number of existing structures (viaducts and bridges) would require widening and/or replacement works. These works would inevitably lead to substantial track possessions and speed restrictions.
- 7.3.8 Rail link options R2A, R2B, R4A and R4B were developed with the intention of improving the existing rail operation performance and robustness of Option R2. Although these alternative options succeed in providing improved rail traffic operation, they do so at the cost of increasing the negative impacts on local communities and businesses, and higher construction costs.

Impact on local community

- 7.3.9 This option family is based on Option R2 which would make use of the NLL corridor, taking additional land only for the widening structures. The impacts on the local community, both temporary and permanent, would be similar to the shared options, with the same number of properties impacted: demolition of one residential, five commercial and two industrial properties. This is confirmed by the Environmental Assessment of July 2012 produced by HS2 to support the hybrid Bill application.
- 7.3.10 Additional negative local impacts for each option can be summarised as:
- Option R2A – additional land take at Caledonian Road Station to facilitate construction of a new platform, footbridge and passive provision for station access.
 - Option R2B – additional land take for the third track section in the vicinity of Juniper Crescent and the Camden Roundhouse, at Morrisons' bridge access and on the north side of Gilbey's Vaults, where the space available is very limited and borders sensitive heritage-listed structures.
 - Option R4A – the combination of construction works to the viaduct around Chalk Farm Road Bridge plus an additional bridge, and associated demolitions to Camden Lock Market stalls and one restaurant, constitutes an adverse impact on the three markets in Camden (Camden Stables, Camden Lock and Camden Canal markets), tourism and local economy. The construction of this widened viaduct would also leave the Grade II listed Roundhouse as close as 1.5 metres from an operational track, which could be considered unacceptable.
 - Option R4B – this option mitigates the risks of building an operational railway in sensitive land and close to heritage structures but would take up the access and car park of the existing Morrisons supermarket, leading to its closure during construction. Given the permanent difficulty of access and reduced car park area, the supermarket

might need to be closed permanently. All the impacts on Camden local markets and the restaurant demolition, as in Option R4A, would also apply to this Option R4B.

- 7.3.11 Options R2A and R2B were developed to improve on the existing rail operation performance and robustness but would potentially bring increased negative impacts on the local community and businesses.
- 7.3.12 Likewise, Options R4A and R4B were developed to avoid the associated impacts with the shared structures and rail operations between the Camden Road West Junction and Primrose Hill, leaving both NLL tracks free for classic rail traffic. They would achieve this, but would increase the effect on the community and local businesses.
- 7.3.13 Rail options R2A, R2B, R4A and R4B could be considered, to some extent, as failed attempts to mitigate Option R2 impacts on the local community, it is considered that Option R2 is reasonably representative of the segregated option family impact on the local community. This is similar to those impacts identified for the shared options, as assessed by the July 2012 Environmental Statement.

Costs

- 7.3.14 The cost estimates presented for all segregated options range from £610 million to £630 million, with Option R2 (NR's 'Enhanced NLL') being the cheapest. All costings were calculated at 2011 prices on the basis of information available, and are inclusive of all construction costs, indirect costs, efficiencies and risk allowances. Cost estimates exclude property purchase and potential compensation costs. A detailed breakdown of these costs by option, along with the source for all costs, is provided in Appendix C.

Benefits

- 7.3.15 Segregated link options provide an effective direct link between HS2 and HS1 and are able to meet the original Sponsor's requirement of three trains per hour in each traffic direction.
- 7.3.16 From a construction point of view, the segregated options have the additional benefit of allowing the tunnel portal to be located clear of the West Coast Mail Line and thus potentially being easier to build.
- 7.3.17 Providing a three trains per hour capability, the segregated options are identified as being capable of accommodating international services at 6tpd and domestic services at 2tph. This would result in a combined morning peak usage projection of around 2,800 passengers, one-way, with the service having a PVB of £4,110 and a PVC (excluding construction costs) of £3,812. Based on internal DfT analysis, this would not offer good value for money.

Risks

- 7.3.18 With a potential increase in demand for HS2 services beyond the initial requirement of three trains per hour in each direction, there would be a risk of increased conflict with classic train operation, as well as with TfL's and NR's future expansion plans.

- 7.3.19 The segregated option also requires more extensive widening and refurbishment of existing structures, namely viaducts and rail bridges. The relative uncertainty around the existing condition of these affected structures could also be considered a risk. In the event that conditions were worse than expected, this could lead to more extensive works and subsequent cost increases.
- 7.3.20 Existing track upgrades and works, in and around existing rail structures, would require works in and around live tracks, with many requiring track possessions.

Passive provision

- 7.3.21 The same passive provision requirements, principles, impacts and cost detailed for the rail surface shared link family of options would apply to the segregated options. This is because of the similar nature of the engineering solution adopted for both rail tunnel plus shared surface operation and rail tunnel plus segregated surface operation (tunnel section from Old Oak Common Station to a tunnel portal somewhere in the Camden area, then using the NLL corridor up to the HS1 link to the NR network).

7.4 Rail tunnel between Old Oak Common and Camden

- 7.4.1 This group of options would use dedicated (segregated) tunnelled rail lines between Old Oak Common and Camden. The primary purpose of any of the rail tunnel central schemes would be to remove the conflict with the existing NLL surface operations schemes for passenger and freight services. The level of capacity that would be provided by these options creates the opportunity for use by domestic services, in addition to providing a link to HS2.
- 7.4.2 These options would involve connecting from HS2 to HS1 in the Camden area. Six different options of this type have previously been developed, these are listed below:

Rail Tunnel between Old Oak Common and Camden Options	Option R1A
	Option R1B
	Option R1C
	Option R3
	Option R5
	Option R6

- 7.4.3 Options R1A to 1C would involve a single bore tunnel from Old Oak Common Station to the immediate vicinity of Camden Road station before joining the existing HS1 link. These would require reconfiguration of the NLL and Camden Road station.
- 7.4.4 Option R3, also known as the "Coffey Tunnel", extends the tunnelled section east to a portal in St Pancras Way. From here, the HS2 track would rise up and pass under the existing NLL to join the existing triangular connection to HS1, immediately west of the bridge over the MML.
- 7.4.5 R6 was reviewed as part of the assessment supporting the HS2 letter to David Prout of 16 July 2013, and would involve a revised central tunnel alignment linking via Agar Grove.

Route

7.4.6 In general, this family of options begins as a single bored tunnel at Old Oak Common Station before emerging east of Camden Road Station, where it rises up to a tunnel portal linking to the existing HS1 route just east of St Pancras Station.

7.4.7 There are a few exceptions to this generic route:

- Rail link option R6 starts from a pair of underground turnout caverns (step plates) at Old Oak Common, connecting directly from the HS2 main lines to the Euston HS2 station. This option would require underground junctions.
- Rail link option R6 is a twin tunnel option.

Link operational capacity

7.4.8 These options have the advantage of providing dedicated track(s) for the HS1-HS2 link service, and would therefore be capable of meeting the HS2 Sponsor's requirement of accommodating three high speed service trains per hour, in each direction. This would be achieved without compromising existing and future NLL rail operation capacity.

7.4.9 Option R6 is a twin bored tunnel link and would allow for a service of up to 16tph according to the HS2 letter to David Prout on 16 July 2013.

Rail operation impact

7.4.10 The extra capacity provided with these options would have an overall positive impact for existing and future rail operations. However, during construction, those options with the tunnel portal ramp emerging within the Camden area would have considerable impacts on existing rail operations:

- Option R1A, R1B – would require reconfiguring the NLL between Camden Road Central Junction and Camden Road West Junction, including Camden Road Station.
- Option R1C – would require reconfiguring the NLL route and Camden Road Station.
- Option R3 – would require refurbishing Camden Road Station platforms 3 and 4, reconstructing metal bridges on the north side of the NLL viaduct, and constructing a new HS2-NLL intersection bridge.
- Option R5 – would require building new viaducts and bridge under the NLL, jacking up the superstructures of two steel bridges over the Midlands Main Line and reconstructing the east abutments, and demolishing two HS1-NLL viaducts as well as extending the flyover over HS1.
- Option R6 – although there is no detailed information on the works necessary to existing rail structures associated with this link option, given that the tunnel portal would be located in the same area of rail link options R3 and R5, we can assume similar interventions would be required.

7.4.11 These interventions would require various and prolonged track possessions which would bring substantial service disruption to the NLL, Midland Main Line and to HS1 (in case of Option R5).

7.4.12 Options RA, R7 and R8 would have no or little impact to existing rail operations since they would avoid any works in the central Camden area.

Impact on local community

7.4.13 Although the option family considers only almost-fully tunnelled routes connecting HS2 and HS1, the land take required for the tunnel portal and the need for extensive works to existing rail structures would lead to impacts on local community and businesses, particularly during construction.

7.4.14 The following impacts are associated with the various options:

- Option R1A, R1B – demolishing seven residential dwellings (some Grade II listed) and four commercial properties, and permanently closing three roads. During construction, temporary road closures and land loss would impact on local community and businesses, owing to building works for the new tunnel portal and NLL reconfiguration.
- Option R1C – demolishing 13 residential dwellings (some Grade II listed) and two commercial properties, and permanently closing four roads. During construction, temporary road closures and land loss would impact on local community and businesses, owing to building works for the new tunnel portal and NLL reconfiguration.
- Option R3 – demolishing 26 residential dwellings (some Grade II listed) and permanently closing four roads. Also, during construction, due to refurbishment works of Camden Road Station and the building of the new high speed link and NLL intersection, temporary road closures and land loss would impact on local community and businesses. Constructing the retained portal approach structure along St Pancras Way Road would substantially affect the properties along this road and have a substantial environmental impact.
- Option R5 – demolishing an unspecified number of dwellings (although it is envisaged that a similar number to Option R3 would be affected). Two existing concrete batching plants and an aggregate delivery rail head would also need to be demolished, owing to the construction of new realigned viaducts. Constructing the extra vent shafts would have an impact, in the loss of green land and community recreational equipment. Given the number of structures to demolish, refurbish and rebuild, together with road and pathways closures, construction activity would bring inevitable disruption and disturbance to the local community and businesses.
- Option R6 – there is no specific environmental impact study for this option. Given the location of its tunnel portal, it would be expected to have a similar impact as described for option R3. In July 2013, HS2 Ltd's CEO Alison Munro wrote to David

Prout, Director General for HS2, that 114 residential dwellings and another seven commercial properties would be affected.

7.4.15 These options would represent a substantial increment to the negative impact to local communities, in comparison with the shared and segregated rail link options.

Costs

Table 19: Costs for rail tunnel between Old Oak Common and Camden options

Scope	Requirement	Cost range (£M)	Option
From Old Oak Common Station to Camden or From HS2 tunnels step plates to Camden	Shortest single bore tunnel link	£653 – £854	Option R1A Option R1B Option R1C Option R3 Option R5
	Shortest twin bore tunnel link	£995	Option R6

7.4.16 Option R1B is the least costly option at £653 million. Whilst tunnelled options would most likely involve a higher capital cost, it is possible that some of the shorter tunnelled options would be in the same cost range as surface segregated link options. A detailed breakdown of these costs by option, along with the source for all costs, is provided in Appendix C.

Benefits

7.4.17 These options provide an effective direct link between HS2 and HS1, and exceed the original Sponsor’s requirement of three trains per hour in each traffic direction with no impacts to both current and future NLL service capacity.

7.4.18 Providing a 3tph capability, these options are capable of accommodating both international services (6tpd) and domestic services (2tph). This would result in a combined morning peak usage projection of around 2,800 passengers (one-way).

7.4.19 Option R6 is for a twin track rail link, which would enable higher service frequencies to be run and potentially generate further (as yet unproven) benefits. Despite this, allowing for the possibility of additional benefits from a higher frequency service is recommended.

7.4.20 HS2 Ltd estimated the capital expenditure required to construct these options as £653m to £995m (2011 prices). DfT internal analysis on the hybrid Bill option indicated that this would not offer good value for money. As the tunnelled options are significantly more costly and would have the same benefits, the implication is that these options would offer poorer value for money than the hybrid Bill option.

Risks

- 7.4.21 Tunnels are complex engineering works and require comprehensive support studies. Given that these options were only developed to concept design stage, there is only limited information available on which to gauge the full extent of potential risks, most of them related to unknown geotechnical conditions and underground structures and services.
- 7.4.22 With the information available to date, it was possible to identify that -for options terminating in the Camden area- tunnels would have to be executed at very shallow depths under a considerable area (800m) of urban soft ground. This scenario would involve a risk of undesired settlement under a 200 year old brick viaduct and Camden Station. The close route to both LUL Northern Line tunnels would also be considered a risk, as would the necessary realignment of existing storm relief and sewers conduits.
- 7.4.23 From a construction point of view, given the technical difficulties of executing tunnels at shallow depths, it would be necessary to further assess alternatives to mined tunnelling techniques, combined with extensive (and expensive) ground treatment. The method is clearly proven in the area on such projects as Crossrail 1.
- 7.4.24 The tunnelled options linking HS2 with HS1 within the Camden area also require widening and refurbishing of existing rail structures such as viaducts and rail bridges. The relative uncertainty around the existing condition of these affected structures and potential utilities diversions could also be considered a risk. Were conditions to be worse than expected, this could lead to more extensive works and subsequent cost increases.
- 7.4.25 Existing track upgrades and works in and around existing rail structures would require works in and around live tracks, with many requiring track possessions.

Passive provision

- 7.4.26 We considered two distinct option subgroups when analysing the passive provision:
- link options starting with a tunnel section from Old Oak Common Station – R1A, R1B, R1C, R3 and R5; and
 - link options starting from a pair of turnout caverns ('step plates') directly from HS2 main lines, between Old Oak Common and Euston – Option R6.
- 7.4.27 In both cases, for the HS1-HS2 link to be deferred to a later HS2 Phase One or beyond, adequate passive provision could be provided in order to eliminate the need for future change to existing operational layouts and mitigate disruption to both existing and high speed rail services.
- 7.4.28 Passive provision costs are set out in Table 20: Costs of passive provision.

Review of HS2-HS1 connectivity and rail links to the continent

Table 20: Costs of passive provision

Passive provision	Cost (£M)	RT Option
Portal and 450m stub tunnel from Old Oak Common Station (single bored tunnel section)	£42	R1A; R1B; R1C; R3; R5
Turnout caverns (x2) including a 50m tunnel stub	£103	R6
7,640m single bored tunnel section	£288	R1A; R1B; R1C (full length)
8,550 m single bored tunnel section	£365	R3; R5 (full length)
3,930m twin tunnel (including step plates)	£621	R6 (full length)

7.5 Rail Options Eastern

7.5.1 The Rail Options Eastern ‘family’ use a dedicated (segregated) longer distance rail tunnel between Old Oak Common and Stratford or beyond which has benefits in terms of reduced conflict with the existing NLL operations. Moreover, due to its long tunnel alignment solution, these options avoid the Camden area resulting in considerably lower impacts to local community and business.

7.5.2 All the longer tunnel options exceed HS2 Ltd’s 3tph Sponsor’s requirement and a number are proposed as twin tunnel options, which would provide opportunities for further increase in service provision. It is however noted that the Eastern Tunnel Options identified significant challenges in connecting to HS1 before or at Stratford International and instead join the HS1 route to the east of Stratford. The lack of interchange at Stratford is expected to significantly reduce benefits associated with domestic services.

7.5.3 In total three different options have been developed, namely:

Rail Tunnelled Eastern	Option RA
	Option R7
	Option R8

7.5.4 Rail link Option RA, considers trains travelling at high speed throughout the HS1-HS2 link, and was abandoned at an early stage of its development; however, details are included for completeness.

7.5.5 Options R7 and R8 were rejected at a very early stage, and therefore have not been included in HS2 reports to date. However, although information is largely preliminary, it was considered that there was sufficient technical and costing data, provided by HS2 Ltd and its consultants, to include them in this report. Nevertheless, it should be stressed that all longer tunnel options have previously been rejected.

Route

7.5.6 These options comprise long tunnel routes to either Rainham or Dagenham, in Essex and are:

- Option RA is a single track option, starting at Old Oak Common Station;
- Rail link options R7 and R8 were developed as twin tunnel options, originated from HS2 tunnels turnout caverns.

Link operational capacity

7.5.7 The operational capacity of Option RA is unclear. As a single bore tunnel over a considerable distance, the provided capacity is considered unlikely to meet the Sponsor’s 3tph requirement. Options R7 and R8 (twin track rail links) would meet the Sponsor’s requirement and potentially support further service provision.

Rail operation impact

7.5.8 Options RA, R7 and R8, would have no or little impact to existing rail operations since they would avoid any works in the central Camden area.

Impact on local communities

7.5.9 The expected impact of these options on local communities has the potential to be substantially mitigated. There is however no specific environmental impact study available for these rail link options.

Costs

7.5.10 Costs for the longer tunnel options are set out in Table 21: Costs for longer tunnelled options.

Table 21: Costs for longer tunnelled options

Scope	Requirement	Cost range (£m)	RTE Option
From Old Oak Common Station	Direct link to HS1 route –high speed link specifications	£5,500 – £6,000	Option RA
or from HS2 tunnels step plates	Direct link to HS1 route – classic rail speed	£2,785 – £3,420	Option R7; Option R8

7.5.11 Costs were calculated at 2011 prices and are inclusive of all construction costs, indirect costs, efficiencies and risk allowances. Cost estimates exclude property purchase and potential compensation costs. A detailed breakdown of these costs by option, along with the source for all costs, is provided in Appendix C.

Benefits

7.5.12 The service capability of Option RA is unclear; however, Options R7 and R8 (twin track rail links) would have the capacity to handle a potential future increase of HS1-HS2 rail link demand. These options are capable of accommodating international services (6tpd) and domestic services (2tph).

7.5.13 The result would be a combined morning peak usage projection of around 2,800 passengers, one-way). HS2 Ltd estimated the capital expenditure required to construct these options at £2,785 million to £6,000 million at 2011 prices. DfT internal analysis on the hybrid Bill option indicated that it did not offer good value for money. The benefits would be higher than for the

segregated surface options, but the high costs imply that they would not offer good value for money.

Risks

- 7.5.14 Tunnels are complex engineering works and require comprehensive support studies. Given that the options reviewed were developed only to concept design stage, there is only limited information available on which to gauge the full extent of potential risks, most of them related to unknown geotechnical conditions and underground structures and services.
- 7.5.15 Options RA, R7 and R8 could be executed at safer depths and are likely to avoid settlement and physical clashes with existing utilities and structures, when comparing with the baseline comparator, it is possible to say that, there is a lower level of risk to the HS1-HS2 link delivery.

Passive provision

- 7.5.16 Passive provision for the longer tunnel options is essentially the same as for the Rail Tunnelled Central options, with a similar distinction between those options starting at Old Oak Common and those starting at the 'step plate' junction. Costs of passive provision can therefore be considered to be similar. This includes its impacts on existing rail operations and local communities both during passive provision construction and at a future date, when the rail link option is completed.

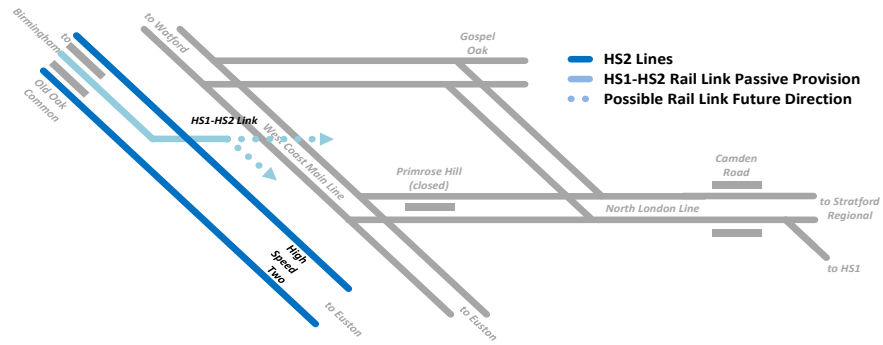
7.6 Rail link passive provision

- 7.6.1 Our definition of passive provision is the minimum amount of works required to enable the potential future construction of a rail link, with acceptable levels of impact on (future) existing services, infrastructure and environment.
- 7.6.2 The selection of the passive provision configuration depends to a limited extent on the link option solution. However, because of potential major uncertainties around cost and deliverability of related infrastructure in the future, it is not considered appropriate to use this as a primary factor in choosing the initial rail option. In other words, the ability to enable passive provision would not 'improve' the performance of any option.
- 7.6.3 Furthermore, there could be a major change in costs of travel (or other factors) in the future, requiring a direct rail link between HS1 and HS2. A combination of increased economic activity in the Midlands or North, increased road travel cost, heavy rail congestion in central London, and changes to border and security controls could result in an increase in demand to the point where a rail-based option would become viable. The levels of disruption to (future) existing rail services, the impacts on local communities and businesses, and increased costs resulting from construction, at a later stage, could be considered unacceptable without passive provision.
- 7.6.4 Two passive provision scenarios have been identified, namely;

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A) Construction of a 450 metre single bore tunnel stub from Old Oak Common Station and allowing the necessary station layout to accommodate the future HS1-HS2 rail link track

Indicative track diagram



Applicable rail link options

All shared link options.
 All segregated link options.
 All central tunnel link options, with the exception of option R6.

Rail operations impact

This passive provision would mitigate the need for future change to existing operational layouts, and minimise disruption to (future) existing HS2 rail services and Old Oak station layout. Although it would have minimal present and future impacts, this passive provision would constrain future operational track layout changes and expansion plans at Old Oak Common.

No change in the level of disruption resulting from the rail link construction on local existing rail operations and HS1 services.

Local impact

As Old Oak Common would be fully operational, this would preclude tunnelling from the station end, and the tunnel construction would have to be resumed from the tunnel portal end in Camden.

The subsequent construction of the Old Oak Common HS1-HS2 link tunnel would require additional land take, to accommodate the tunnel boring worksite.

By resuming the tunnel boring from the tunnel portal end, the excavated materials from the tunnel excavation would have to be taken out from this same area in Camden (also assuming that removal of material from an intermediate shaft by road is ruled out). Material removal from Camden would lead to increased local traffic disruption, land take, additional property demolition and associated compensation.

If these additional future impacts are considered unacceptable (as passive provision that has already been rejected in the November 2013 HS2 London-West Midlands Environmental Statement), the only alternative passive provision for this Rail Surface Shared option type may be constructing the entire tunnel length during HS2 Phase One, starting from Old Oak Common Station and emerging within the Camden area.

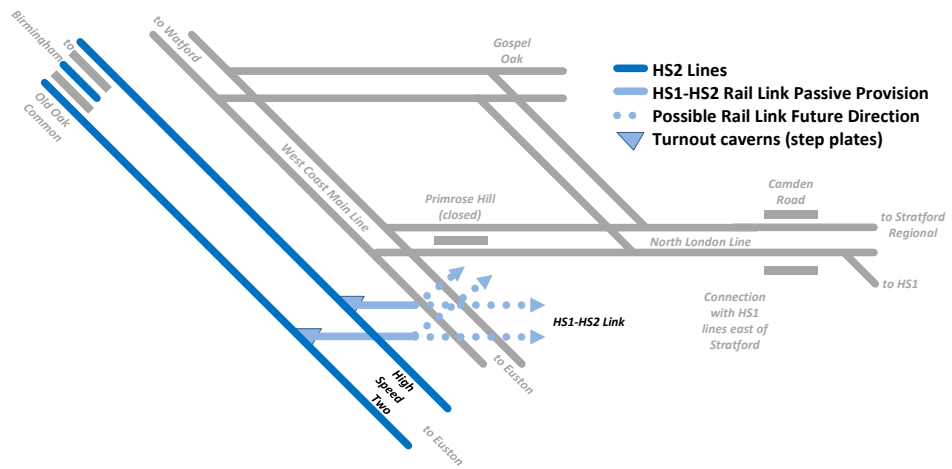
Cost

The estimated cost of constructing 450m of a tunnel stub from Old Oak Common is around £42 million (at 2011 prices).

Alternatively, the cost of building the entire length of the HS1-HS2 link tunnel would cost between £265 million and £355 million (at 2011 prices).

B) Construction of two turnout caverns (step plates) from HS2 rail tunnels, including a 50m tunnel stub on each cavern and allowing the necessary Old Oak Station layout to accommodate the future HS1-HS2 rail link track

Indicative track diagram



Applicable rail link options

All longer tunnel link options and central tunnel option R6.

Rail operations impact

This passive provision would mitigate the need for future changes to existing operational layouts, and limit disruption to (future) existing HS2 rail services and the Old Oak station layout.

Similar level of disruption from the rail link construction on local existing rail operations and HS1 services.

Underground junction required.

Local impact

Again, as Old Oak Common will be fully operational, the tunnel construction would have to be resumed from the tunnel portal end.

The turnout caverns would need to be built via a shaft. If the current shafts cannot be used, new shafts would need to be located and powers obtained. The caverns would need to be built in advance of tunnel boring machines (TBM) arriving from Old Oak Common, which might have programme implications as the Euston tunnels are on the critical path.

Depending on the construction strategy developed, it is likely that constructing the HS1-HS2 link tunnel would require additional land take to accommodate the tunnel boring worksite elsewhere, at Agar Grove (R6) or possibly at Dagenham (R7; R8), although this would be subject to substantial further assessment. Consideration of the R6 link option indicates that the passive provision requirements would be the same as those described in A, and common with those schemes through Camden.

Cost

The estimated cost of constructing two turnout caverns, including 50m of a tunnel stub from HS2 rail tunnels, is around £103 million (at 2011 prices).

For R6 link option, with full length twin bore tunnel, including the turnout caverns, the overall estimate is £621 million.

7.6.5 The 450m stub tunnel and/or the turnout caverns would need to be constructed in tandem with the overall programme for the HS2 main line tunnels between Old Oak Common and Euston (HS2 Phase One).

- 7.6.6 Studies into the cost of deferring overall construction until after Phase One or Phase Two are sparse. Available data suggests that the overall construction cost of a deferred rail option could be a minimum of 5% to 20% higher than if the same rail link was executed during HS2 Phase One. This increase would be a consequence of the added construction complexity, along with additional land take, property purchase and demolition required.
- 7.6.7 No work has been undertaken on constructing the rail link at a later stage without passive provision, so the impacts are largely unknown. Making use of realistic assumptions, requirements would include:
- Tunnels driven from a suitable site to the east of Old Oak Common Station, such as Camden.
 - Old Oak Common station box width allows for three tunnels (current design option).
 - Abandon tunnel boring machine skin buried in the ground and remove all other components through drive pit.
 - Dismantle tunnel boring machine cutter head at Old Oak Common Station.
- 7.6.8 It is possible, in addition to the impacts described earlier in this section, that constructing a rail link at a later stage without adequate passive provision could result in the following interfaces and impacts on HS2 infrastructure and operation:
- Enabling works on surface at Old Oak Common Station to provide a site, access to site and access to lower level of OOC. Time impact: 9-12 months.
 - Reconfiguring passenger escape/intervention at east end of OOC to allow for construction. Time impact: 6-9 months.
 - Strengthening OOC headwall and constructing SCL stub. Time impact: 6-9 months.
 - Constructing new passenger escape/intervention point at east end of OOC. Time impact: 3-4 months.
 - Installing new track turnout at east of OOC to allow for international services, requiring cutting out of existing track bed, modifications to walkways, drainage and track work. Time impact: 3-4 months.
 - Modifying existing HS2 signalling system, track work and overhead line electrification at east end of OOC for new international connection. Time impact: 3-4 months.
 - In parallel with the tunnel work, reconfiguring the ventilation provision at OOC along with new structures for international facilities. Time impact: 9-18 months.
 - In parallel with the tunnel and station works, providing additional tunnels and connections at the intermediate shafts, possibly including modifications to ventilation equipment, mechanical and electrical equipment and railway systems.

- 7.6.9 Overall, in and around Old Oak Common Station as well as along the link tunnel route, the definition, planning and execution of the above additional works could take between three and four years and involve substantial costs. The disruption to HS2 operations is unclear without further detailed studies, but several extended service interruption periods would be required. Negotiations and planning for possessions and closures with train operating companies would be likely to run for a period of between three to five years.

8 Assessment of alternative rail options

8.1 Introduction

8.1.1 Alternative rail options have been defined as any options not previously considered under the categories of rail or APM options. A review of the petitions relating to the HS2-HS1 link, and consideration of the wider public transport context, was used to identify a range of strategic alternatives to the options previously assessed.

8.1.2 We looked at the petition items raised in response to the hybrid Bill to ascertain whether any of the options petitioned for fell outside those options considered under the rail and non-rail categories. Broadly speaking, the petitions can be grouped under the following headings:

- petitions in favour of a link, but with no specific option favoured
- petitions opposed to the link;
- options relating to passive provision (considered under rail options);
- additional options not covered above:
 - West London Line (Petition 1346)
 - Kings Cross tunnels (Petition 327)
 - Euston Cross passive provision (Petition 533)
 - tunnelling under Euston Station (Petition 1057)
 - Greengauge 21 proposals.

8.2 West London Line group petition

8.2.1 The petition from the West London group states:

"The HS2 lines from Birmingham are physically linked to the West London Line to Clapham Junction in both directions to allow through trains between HS2 and HS1 via the West London Line, Brighton Main Line and the Redhill - Tonbridge - Ashford Line."

8.2.2 Our interpretation of this scenario is that services from Birmingham would run to Old Oak Common then to Clapham Junction (via West London Line), Clapham Junction-East Croydon (via South London Line), East Croydon-Redhill (Brighton Main Line and Redhill-Ashford (via the Ashford Line). This is shown in Appendix E.

Link operational capacity

8.2.3 The routes used by the proposal are already operating at or near to full capacity. In particular:

- The WLL already operates with five stopping trains per hour (four TfL and one

Southern) plus freights. TfL has plans to increase the quantum of its services to six per hour. Any HS2 service would have to run on the route at stopping train speed.

- The Brighton Main Line south of Clapham Junction is also operating at full capacity. The WLL connections emerge onto the slow lines over a 20mph flat junction, and it is not possible at peak for the existing Milton Keynes to Clapham Junction service to proceed any further south because of insufficient track access. The only probable solution to this would be to cancel some services from Victoria to provide capacity for HS2 services to join the BML at Falcon Junction.
- Even if a south exit could be arranged, the train would have to proceed on the slow lines until East Croydon. The only intermediate crossing point, at Balham, is at grade and cannot be used for such moves in the peak without consuming paths in both directions on both the fast and slow lines.
- South of East Croydon, trains could run on the fast lines and cross to the slow lines at Stoats Nest Junction (or run slow line from East Croydon). They could then run via Redhill – this move is already regularly made.
- The section between Redhill and Tonbridge would need re-signalling as it has very long block sections at present, and does not have spare peak hour capacity. This section of route will be operating at near full-capacity once the Thameslink service is fully introduced in 2018.
- The South Eastern Main Line between Tonbridge and Ashford is also operating at near full-capacity. It is not clear if there would be sufficient capacity at the flat junctions at Tonbridge and Ashford for additional trains during the peak. A flyover may be required at Tonbridge.

Rail operations impacts

Track levels

- 8.2.4 The HS2 tracks at Old Oak Common are approximately 18 metres below ground level - approximately the level of the GWML. The WLL running line through the platforms would have to be approximately 10 metres above the GWML. It is not clear how a ramp between the two could be constructed; at 3% gradient, this ramp would need to be approximately 900 metres long. Grade-separated junctions onto the WLL would be required.

Train length

- 8.2.5 None of the platforms on any station in Sussex or Kent can accommodate a train of 400 metres length, while trains of this length will foul a number of junctions at the rear when standing at signals. This would be likely to cause very significant operational disruption, and trains would not be able to make any service call at an intermediate point. A 400 metre train would consume more than one train path and possibly impose junction constraints. The only satisfactory solution would be to run the train as a single 200 metre classic-compatible set as far as Ashford (this type of stock will already have NR-compatible signalling systems fitted). It

is not economic to run a 200 metre train through the Channel Tunnel, where track access is charged according to paths, so the set would have to be combined with another at Ashford. There is platform capacity to do this, but it is not clear what the second set would then do, as there is no stabling facility nearby. This operational concept is unlikely to provide an economic solution. At present, only three services per day operate between Ashford and Paris, and one per day to Brussels. It is doubtful that there is sufficient patronage to fill a 200 metre set from Ashford on a frequent basis.

Intermediate station calls

- 8.2.6 Existing stock running in Kent and Sussex is configured for quick loading and unloading. Multiple intermediate door positions are provided. It takes much longer for passengers to board High Speed stock. The network in Kent and Sussex is not configured for this, and longer station dwells would use up at least two train paths-worth of route capacity for each call. Existing routes might not be able to accommodate this without reductions in domestic service levels.

Traction power

- 8.2.7 Any rolling stock using this route would need to be equipped for dual voltage (25kV AVC? overhead and 750V DC third rail). The only high speed stock capable of this is the current Eurostar fleet, which will be life-expired by 2026. It would be uneconomic to specify a small bespoke fleet of dual voltage units. At present, HS2 has no plans to procure rolling stock with other than 25 kV AC traction power.

Fleet size

- 8.2.8 The HS2 fleet is sized to provide services between London and the North. There is no provision in the current business plan or operational plans for international traffic. There is equally no plan to serve stations south of the Thames with domestic services.

Benefits

Journey times

- 8.2.9 The current journey time from St Pancras to Ashford via HS1 is approximately 30 minutes. Assuming paths over the WLL and BML to East Croydon are at stopping train speeds (see above), but taking an optimistic view of what would be achievable, the journey time from Old Oak Common to Ashford (without station calls) would be approximately:

- | | |
|-----------------------------------|------------|
| • OOC - Clapham Junction | 15 minutes |
| • Clapham Junction – East Croydon | 22 minutes |
| • East Croydon – Redhill | 12 minutes |
| • Redhill – Tonbridge | 20 minutes |
| • Tonbridge – Ashford | 25 minutes |
| • Total journey time | 94 minutes |

- 8.2.10 Allowing for customs and passport control and interchange penalty, this equates to a generalised time between Old Oak Common and Ashford of around 154 minutes, compared to 100 minutes for other rail options.
- 8.2.11 Extended journey times of this nature would substantially reduce the expected mode share which an international service might achieve.
- 8.2.12 An interesting reference point for this option is that overall journey times from Birmingham to Paris via this route would in fact be slightly longer than the historically planned Eurostar 'North of London' services, for which rail infrastructure and rolling stock already exist.

Customs facilities

- 8.2.13 Unless trains are operated as through-services without intermediate stops, trains and their passengers would require customs and passport clearance at Ashford. This would require complete disembarkation. This would be required in any case if any train called at an intermediate point (whether for planned or unplanned reasons). Passenger and luggage clearance would take at least 30 minutes. Facilities for processing international passengers have been provided at HS2 stations. Even if clearance were not carried out at Ashford, time would still be required to join sets as outlined above.

Costs

- 8.2.14 Owing to the issues noted above on link capacity, rail operations and journey time disbenefits, no costings have been worked up for this option.

Kings Cross tunnels

- 8.2.15 The petition from Anthony Herman Kay states:

"The possibilities of using the existing tunnels out of Kings Cross should be fully investigated, as it has also been suggested that there is in fact space there to accommodate any new platforms, so the mammoth tunnelling and destruction of homes and businesses around Euston would then be avoided, and a further advantage is that there would be a link automatically with HS1."

- 8.2.16 A review of this proposal has been undertaken with reference to the Route Engineering study, 2009. This documents the full range of locations considered for the the HS2 London Terminal, and included reviews of a range of options located in the Kings Cross Lands and at St Pancras.
- 8.2.17 Options terminating at St Pancras were not progressed beyond Stage 2 (July 2009) of this review process. Kings Cross options were among a number of possibilities considered as part of the Stage 3 review. Following appraisal by HS2 Ltd, these were not progressed.
- 8.2.18 The process which led to the selection of Euston as the London Terminal considered a number of alternatives comparable with the petition proposal. Although these options have a number of merits, including good connections to HS1, previous reviews of the full range of station options identified Euston as the preferred terminal option.

Euston Cross / Tunnel under Euston Station

8.2.19 Two related options are proposed by petitioners, which relate to the Euston Cross station proposal or variants.

8.2.20 The petition from Graeme Phillips states:

"Favours Euston Cross option and believes will also serve to connect Midlands and Kent. Also asks for passive provision to enable it later on."

8.2.21 The petition from Antonietta Winton states:

"This could be a tunnel below the existing tracks which would form a new underground terminus at Euston. Or it could be a tunnel arriving at Euston from the west rather than the north. This tunnel would lead to an underground interchange station between Euston and St. Pancras with trains continuing eastward in a tunnel to Stratford and HS1. Such a station could be shared with the planned Crossrail 2."

8.2.22 The Euston Cross option was reviewed as part of the Euston Cross study, completed in December 2013. This concluded that:

"...whilst the concept does permit through-services from Kent to the North and there are operational advantages associated with reducing the number of trains that terminate in Central London, there are significant issues...[including]:

- Additional journey time for the majority of users who are projected to be travelling to central London destinations and require access to the Underground and other methods of surface travel.
- Lack of feasible connection point to HS1 leading to 22km of additional tunnelling and an additional station at Stratford with associated capital and operating cost penalties.
- Increased demolition of residential units compared with the proposed scheme."

8.2.23 On this basis, the proposed Euston Terminal scheme was retained as the preferred station option.

Costs

8.2.24 Costs for the Euston Cross option have been estimated based on Q 2012 prices and exclude systems (assumed allowance of £800 million to £900 million), land and property, indirect costs, efficiency and contingency (HS2 adjustments). The costs are set out in Table 22: Euston Cross construction costs

Table 22: Euston Cross construction costs

Option 'family'	Cost £million		
	Link tunnels	Euston Station	Stratford Station
Euston Cross	£2,060 - £2,450	£1,850-£1,960	£390

Integration with Crossrail 2

8.2.25 The Euston Cross study did not specifically review options for integration with the Euston-St Pancras station put forward as part of the Crossrail 2 proposals. High-level review of this option highlights the following points to consider:

- The proposed Euston Cross station site is offset northwards from the planned Crossrail 2 station location but the extent of tunnelling required, including running lines, turnback sidings and the provision of an APM connection between the Euston Cross station and Euston underground station means that co-ordination with Crossrail 2 proposals is likely to be highly challenging.
- On this basis, integration with Crossrail 2 is thought to present an increased risk for a Euston Cross proposal.
- The current proposed location of the Crossrail 2 station has been selected to maximise connectivity to Euston and St Pancras stations. Given the constraints on location, the proposed location of Euston Cross is noticeably further north. It is assumed that any integrated station would be located on a similar footprint.
- The potential benefits of an integrated design are unclear and potentially negative, depending on the relative weightings given to connections from Crossrail 2 to HS2, St Pancras, Euston Station and local homes and businesses.

Passive provision for Euston Cross

8.2.26 The Euston Cross proposals assume that the main running tunnels are diverted to an alternative alignment. This results in significant impacts in the track arrangements at Old Oak Common.

8.2.27 Two route configuration options were considered as part of the study. Neither of these allows for full operation of both the proposed Euston Station option and the Euston Cross station option.

8.2.28 Further assessment would be required to understand the feasibility and costs of achieving this level of functionality.

8.3 Greengauge 21 proposals

8.3.1 The Greengauge 21 reports ("Travel market demand and the HS1-HS2 link", 2013, and "HS1-HS2 connection: A way forward", 2014) promote the benefits of a high speed, high capacity (more than 3tph) connection between Stratford International and Old Oak Common.

8.3.2 Our review of the functionality achieved by the various rail link options indicates that this capability is not achieved by any option under consideration.

8.3.3 The rail options providing the closest match to this aspiration are as follows:

- R#6 - not a High Speed link.

- R#7 and R#8 - these do not provide a connection to Stratford International.
- Following review of the Euston Cross proposals, it is considered that a composite option is available, combining a twin bore tunnel (as envisaged by R#7 and R#8) with the Euston Cross proposal for connection to Stratford.
- Although discounted as a stand-alone proposal, the Euston Cross study identified that it would be possible to achieve a high speed, high capacity, tunnelled connection with a station stop at Stratford. This would not connect to Stratford International, as tunnel connections from HS2 to either the HS1 tunnel or station box are considered infeasible, but would instead involve the construction of a new station box immediately to the north of Stratford International.

Link operational capacity

- 8.3.4 Both composite options are twin track solutions and would meet the Sponsor’s requirement and support further service provision.

Rail operation impact

- 8.3.5 As with options based on R#7 or R#8, these options will have no or little impact to existing rail operations since they would avoid any works in the central Camden area.

Impact on local community

- 8.3.6 As with the Rail Options Eastern, all options with tunnel portal ramps (or turnout cavern shafts), beyond the Camden area, have the potential to substantially mitigate the expected impact to local communities.
- 8.3.7 No specific environmental impact study is available for these rail link options, but since the required surface works would be much more limited and would be expected to occur in a less populated area, it is assumed that there would be impacts to local communities no worse than the ones measured for the baseline scheme.
- 8.3.8 Impacts in the vicinity of the Stratford area to support construction of the new station facilities could be substantial and would require review.

Costs

- 8.3.9 Costs for the RT options can be segregated as follows:

Table 23: Costs for the RT options

Scope	Requirement	Cost range (£M)	Tunnelled option
Base costs	Direct link to HS1 route (avoiding Camden area)	£2,785 – £3,420	Option R#7; Option R#8
OOO/Step plate to Rainham/Dagenham	High speed link specifications	£5,500 – £6,000	Option RA

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Additional costs			
New station at Stratford	Station box and fit out	£390 ³¹	Both options

8.3.10 On the basis of information available, all costs were calculated at 2011 prices and are inclusive of all construction costs, indirect costs, efficiencies and risk allowances. Cost estimates exclude property purchase and potential compensation costs.

Benefits

8.3.11 The Greengauge 21 proposals would provide a 3tph capability and have spare capacity for potential future increases in demand for an HS1-HS2 rail link.

8.3.12 Three trains-per-hour options are identified as being capable of accommodating both international services (6tpd) and domestic services (2tph). This would result in a combined morning peak usage projection of almost 3,000 passengers (one-way), with the services together having a NPV of £927 million, excluding construction costs.

8.3.13 The additional benefits from a higher frequency service have not been proven, however although we recommend allowing for this possibility. On this basis the benefits of a higher capacity link are estimated as having an NPV of £1,177 million, excluding construction costs.

³¹ Q3 2012 prices - excluding systems (assumed allowance of £800m to £900m), land and property, indirect costs, efficiency and contingency (HS2 adjustments).

9 Assessment of APM and travelator options

9.1 Introduction and option 'families'

9.1.1 This chapter describes the assessment of the non-rail options as presented in the 2010 report, Automated People Mover (APM) - Euston Station to St Pancras International, and in High Speed Rail: London to the West Midlands and beyond - Supplementary Report, HS2, September 2010. As with the rail options, there is a long list of options which can be usefully grouped into families that share similar characteristics. The options are:

- Option NRA – Elevated APM - Phoenix Road
- Option NRB – Sub-surface APM - Phoenix Road
- Option NRC – Elevated APM - Phoenix Road, with direct Euston access
- Option NRD – Elevated (looped) APM
- Option NRE – Elevated APM - Polygon Road
- Option NRF – Sub-surface APM – Polygon Road
- Option NRG – Elevated travelator
- Option NRH – Elevated walkway.

9.1.2 These have been organised into three option 'families' as set out in Table 24: APM and travelator options:

Table 24: APM and travelator options

Option 'family'	Description	Construction cost £m	Benefit £m
Sub-surface APM	APM link options that use dedicated tunnels (sub-surface) below the road/surface infrastructure	£212m to £248m	£225m
Elevated APM	APM link options that are elevated above the road/surface infrastructure	£177m to £226m	£225m
Elevated travelator or Elevated walkway	Walking route options that would be introduced as elevated links between Euston and St Pancras	£120m travelator £85m walkway	Not estimated

9.1.3 The HS2 supplementary report noted that:

- any street level APM options would be too disruptive to road traffic

³² HS2 estimates that "a people-mover link could deliver approximately £225 million worth of benefits for HS2 passengers. It is important to note, however, that the large majority of the benefits would accrue to non-HS2 passengers. The business case for the link is only remotely related to the case for HS2". Source: *High Speed Rail London to the West Midlands and beyond - Supplementary Report. A report to Government by High Speed Two Limited.*

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- it would not be feasible to provide a link at any level along Euston Road
- a fixed-track APM would be the preferred system.

9.1.4 For this reason, the supplementary report considered elevated and sub-surface APM options along Phoenix Road or Polygon Road, north of Euston Road, in more detail.

9.1.5 Figure 18: Impression of elevated APM at Euston Station shows an impression of an elevated APM system at Euston station. The report also considered the option for a travelator, but concluded that peak hour demand was likely to significantly exceed travelator capacity, although this would be a result of background rather than international demand. Our review of potential usage for non-rail links, as set out in section 3, indicates that a travelator option would be expected to provide sufficient capacity, so this option is included in this review.

9.1.6 An APM would take approximately two minutes to travel between Euston and St Pancras. Given that there would be an APM in each direction, services would run on a frequency of every two to three minutes. It could have a maximum capacity of about 10,000 passengers per hour, including loading and unloading time.



Figure 18: Impression of elevated APM at Euston Station

9.1.7 Security and Border Agency advice is that domestic and international passengers would need to be segregated at interchanges and that HS2 international services could not carry domestic passengers. For APM options, we have assumed that international passengers would use a publicly available route and system, and would require immigration and customs control at St Pancras station.

9.2 Sub-surface APM

9.2.1 The sub-surface APM options proposed would link Euston and St Pancras stations via dedicated, tunnelled routes connecting to APM stations beneath Eversholt Street (at the Euston Station end) and Midland Road/British Library (at the London St Pancras end). These would enable passengers to transfer between HS1 and HS2. Two options for this concept have been developed.

Route

9.2.2 Option NRB includes a proposed sub-surface east-west APM route beneath Phoenix Road. The route would turn southwards at both the Eversholt Street and Midland Road ends to APM stations with links to the concourses at both Euston and St Pancras Stations. At Euston, the APM station would be at the same level as the main line platforms, with access to the concourse above via escalators. At St Pancras, the APM station would be at a level similar to that of the Thameslink Station, with access via a walkway above the station (but below road level) crossing to the Thameslink box.

9.2.3 The proposed alignment for Option NRF is beneath Polygon Road with the guideway turning south at Eversholt Street and Midland Road to APM stations with concourse links at both Euston Station and London St Pancras. Polygon Road is not continuous for the full east-west route, so it would be necessary to partially demolish existing Camden housing (Somers Town Site B, 1975) to complete the corridor. At St Pancras, the APM station would be parallel to the Thameslink Station partially beneath the site behind the British Library

9.2.4 It is anticipated that, to complete the route along Polygon Road, the following demolitions would be required:

- Coopers Lane East Community Hall
- 1 x two storey residential block
- 2 x four storey blocks
- old arch wall along Midland Road (remains of former coal depot site).

9.2.5 These routes are shown in Figure 19: Indicative sub-surface APM options. For both sub-surface options, the APM routes would be located within cut-and-cover tunnels approximately 7.5 metres below road level. The option of a bored tunnel was rejected owing to the depth of the tunnel (twice diameter) and the requirement for large reception and launch shafts at either end for the tunnel boring machine, which would require property acquisition and associated disruption. The tunnels would include running tracks, service access, escape routes and service corridor for diverted utilities. It is anticipated that the total width of the tunnel would be approximately 10 metres.

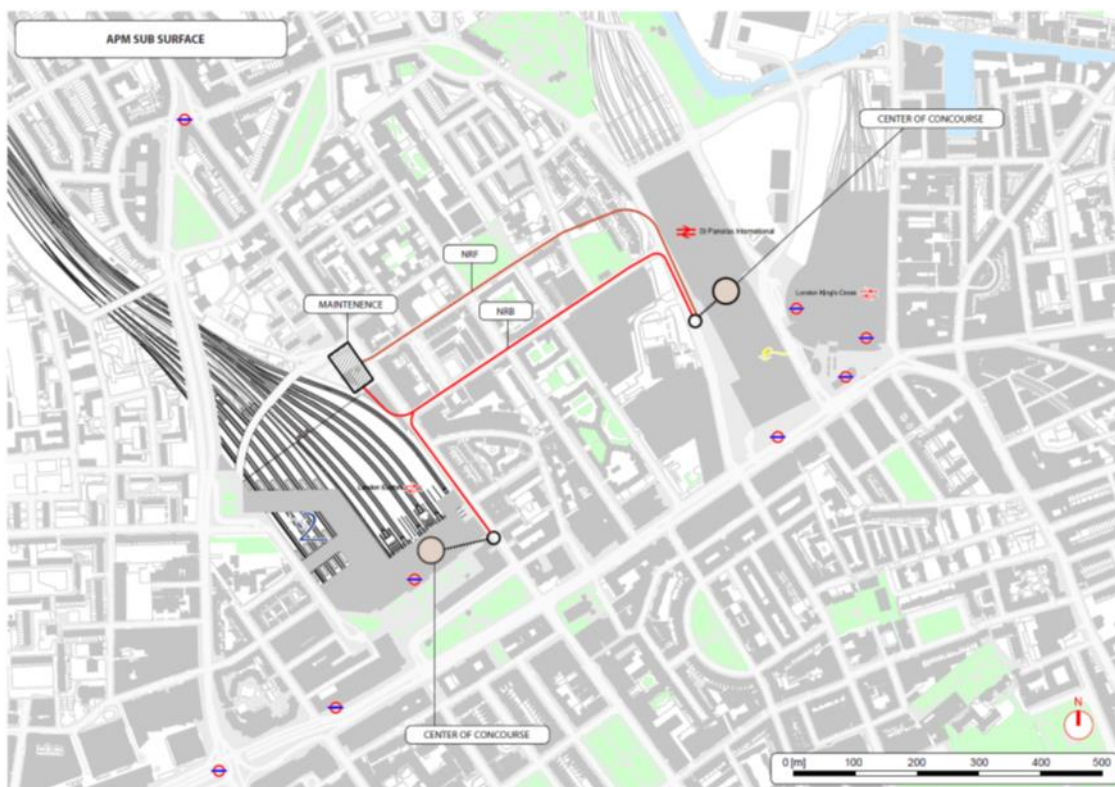


Figure 19: Indicative sub-surface APM options

Link operational capacity

- 9.2.6 Based on the distance between the proposed stations at Euston and St Pancras, and accounting for dwell times at either end for boarding and alighting passengers, the maximum level of frequency is likely to be one APM shuttle every 2 or 3 minutes in each direction. This equates to approximately 20-30 shuttles per hour in each direction, which could carry a total of 10,000 passengers per hour. The forecast demand for the link is for up to 800 international passengers during the peak 3 hour period, although it is acknowledged that the APM could also be used by a significant number of non-international passengers during the peak period. The APM system would have sufficient capacity to accommodate the numbers of expected passengers that are likely to use the link.

Rail operation impact

- 9.2.7 The sub-surface options would operate along non-rail corridors and so would not impact on existing rail operations. Construction at the Euston and St. Pancras ends would impact on rail passengers, but it is assumed that there will be no impact on rail services at these two stations.

Compatibility with hybrid Bill design at Euston station

- 9.2.8 The hybrid Bill is the baseline comparator against which all these options are compared. In each case, it is important to consider whether the option is compatible with the hybrid Bill

design. The proposed entrance to the APM sub-surface route would be via the western footway on Eversholt Street, between the ramp entrance to the One Eversholt Street building and Gate M - the entrance to the existing station basement. If this location is selected, it would probably require the closure of the Gate M ramp during construction, and possibly as part of the final scheme. Gate M is used for deliveries to the retail and catering operators serving the conventional and High Speed concourse retail and catering units at the southern end of the station, and also to London Underground. It is integral to the hybrid Bill servicing strategy. It is unlikely that Eversholt Street would be wide enough to accommodate the entrance without significant disruption to the proposed station entrances in this location.

- 9.2.9 The proposed maintenance depot area north of the station on Eversholt Street provides a wider range of important functions as part of the hybrid Bill design. First, it allows access to the Parcels Deck and provides vehicle security control measures including vehicle rejection facilities. The Parcels Deck delivery and servicing area will primarily be used for deliveries to station users and to retail and catering operators serving the High Speed concourse retail and catering units at the northern end of the station. The Parcels Deck has been designed to contain 18 bays of various sizes. This ramp access is central to the hybrid Bill design and would have to be accommodated within any design for the APM maintenance area. Second, it contains a permanent sub-station which has been relocated to this area and provides power for the station. This again would have to be retained in this area, with access for service vehicles. Last, the area identified for maintenance provides space for buses to layover. The bus layover will be operated by TfL London Buses. The bus layover area provides space for eight buses to layover and then connect to existing and future bus routes on Eversholt Street.

Impact on local community

- 9.2.10 For both sub-surface APM options, there is the potential for significant disruption to the local community during construction. This includes:
- highly disruptive works on Eversholt Street to construct the cut-and-cover tunnel box;
 - road closures for temporary and permanent services diversions and tunnel construction works;
 - loss of access to properties fronting, or in the vicinity of, roads on the APM routes;
 - noise and dust during construction;
 - potentially mitigating foundation works to existing structures to safeguard against damage during construction;
 - diversion of bus services would require diversion from Eversholt Street;
 - severance of communities north and south of the road, including residential school and communal facilities;
 - vehicle movements associated with construction
 - severance of utilities servicing properties.
-

- 9.2.11 Cut-and-cover construction would require installation of piled walls along either edge of the new route very close to adjacent property, making these properties uninhabitable during construction and possibly permanently. It might also be necessary to demolish some properties, were their foundations to be compromised by the piled walls. An alternative to cut-and-cover would be to use tunnel-boring machines but this would require large reception and launch shafts at either end, entailing additional land take, including some of the British Library, probably making it impractical.

Costs

- 9.2.12 Construction costs, including risk and optimism bias, are set out in Table 25: Sub-surface APM construction costs and are presented in more detail in Appendix C.

Table 25: Sub-surface APM construction costs

Option family	Cost
Sub-surface APM	£212m to £248m depending on route alignment, including risk and optimism bias

Benefits

- 9.2.13 Potential demand for a sub-surface APM is estimated at between 3,250 and 3,800 passengers in the morning peak period, the majority of which would be local trips originating at Euston or traversing the Euston area. Up to 800 international passengers could use the system during the peak period, which equates to just over 3,000 per day.
- 9.2.14 Journey times are comparable with a number of the existing travel options, with in-vehicle times and service frequencies comparable to London Underground services. The GJT for international passengers between Old Oak Common and Stratford, with a sub-surface APM in the Euston area is estimated at around 160 minutes, including time spent interchanging and waiting for APM and HS1 services.
- 9.2.15 The benefits of a sub-surface APM system linking Euston and St Pancras would include a relatively quick and frequent service, which could provide journey opportunities to non-international travellers. Indeed, a significant element of the benefits arising from an APM between Euston and St Pancras results from improved links for local commuters rather than improved links between HS2 and HS1.

9.3 Elevated APM

- 9.3.1 The elevated APM options would provide dedicated, elevated links between Euston Station and London St Pancras to transfer passengers between HS1 and HS2.

Route

- 9.3.2 Four elevated APM options were proposed within the 2010 report, Automated People Mover (APM) Euston Station to St Pancras International.
- 9.3.3 Option NRA would run east-west along Phoenix Road, traversing south to a proposed APM station (at high level) parallel to the classic platforms at Euston Station. At Midland Road, the

guideway would similarly turn south and terminate at an APM station parallel to the Midland Road platforms at St Pancras International.

- 9.3.4 Option NRC would run east-west along Phoenix Road. At the Euston Station APM terminus, the guideway would slope down into Euston Station after crossing Eversholt Street. The APM station would be located at concourse level. The benefit of this option would be that direct access to concourse level provides optimum access for rail passengers.
- 9.3.5 Option NRD proposes an elevated APM single-track loop route running along Phoenix Road, Midland Road, Euston Road and Eversholt Street.
- 9.3.6 Option NRE runs east-west along Polygon Road. At Eversholt Street, the proposed guideway would traverse south to a station at high level, on top of the classic platforms at Euston station. At Midland Road, the guideway would likewise turn south to a station located parallel to the Midland Road platforms at St Pancras International station. As with sub-surface APM option NRF, it would be necessary to partially demolish existing Camden housing (Somers Town Site B, 1975) to create a complete corridor along Polygon Road.
- 9.3.7 Of these four options, options NRC (Phoenix Road) and NRE (Polygon Road) were developed in more detail to assess the likely constructability and impact of the schemes. The route options are shown in Figure 20: Indicative elevated APM options.

Link operational capacity

- 9.3.8 For the elevated systems, the guideways would be based on shuttle operation with two guideways carrying one APM each shuttling between stations. The guideways would be formed in reinforced concrete with concrete columns at approximately 11 metre intervals supporting the six metre-high structure with a cross -width of approximately 4.4 metres. The proposed maintenance depot would be sited on the disused post office depot to the north-east of Euston station.
- 9.3.9 The operational capacity of - and therefore demand for- the sub-surface and elevated APM options is assumed to be similar.

Rail operation impact

- 9.3.10 The sub-surface options would operate along non-rail corridors and so would not impact on existing rail operations. Construction at the Euston and St. Pancras ends would impact on rail passengers but it is assumed that there will be no impact on rail services at these two stations.

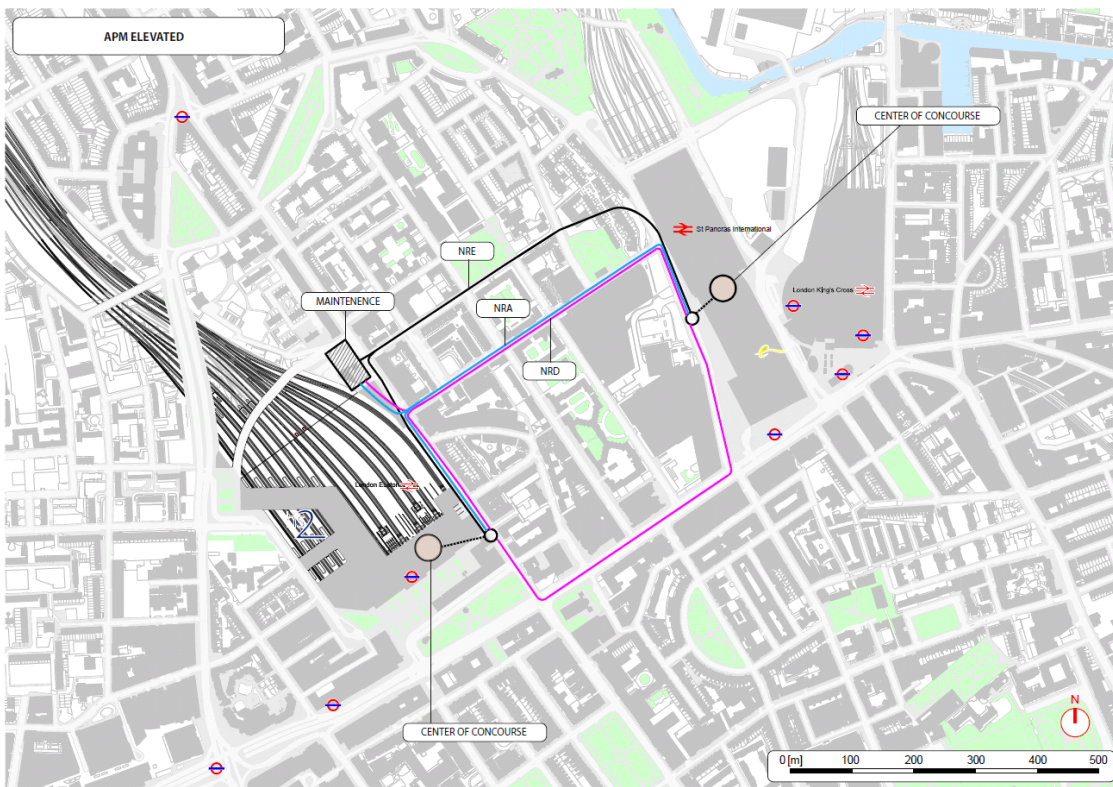


Figure 20: Indicative elevated APM options

Compatibility with hybrid Bill design at Euston station

- 9.3.11 For options NRC and NRE, the proposal envisages that the guideway would traverse south to a station at high level, above the classic platforms at Euston station. This is incompatible with the roof height above the reconstructed Parcels Deck in the hybrid Bill design, which is at +38.00m.
- 9.3.12 For options NRD and NRA, as detailed for the sub-surface options, the proposed entrance to the APM via the western footway on Eversholt Street would be incompatible with the hybrid Bill station entrance from Eversholt Street, the ramp entrance to basement servicing area via Gate M, and the available footway width on Eversholt Street.
- 9.3.13 For all options, as detailed for the sub-surface options, the proposed maintenance depot area to the north of the station would be incompatible with access to the Parcels Deck - including vehicle security control measures, the location and maintenance of a permanent sub-station (PS1) providing power for the station, and the bus layover area providing space for eight buses to layover.

Impact on local community

- 9.3.14 The elevated people mover options on either Phoenix or Polygon Road would have substantial local environmental impacts in the Somers Town residential area. The Polygon Road route would require residential properties between Purchase Street and Midland Road to be demolished, as well as land take from two open spaces including an adventure playground

and a residential open space. The Phoenix Road-Brill Place route would affect a major development proposal for a medical research facility adjacent to the British Library.

9.3.15 Major visual intrusion would occur for each option, as the APM would run adjacent to the upper storey windows of residential properties, schools, local offices and local business premises. These would be more acute for the Polygon Road option, as this potential route is narrower than Phoenix Road. The Phoenix Road-Brill Place route would affect the setting of three Grade II listed buildings. Both options would also require the removal of established trees, which currently form the 'green' part of the streetscape of the built-up Somers Town area.

9.3.16 Although the effects of noise could be contained through modern design and mitigation measures, the elevated nature of the routes and their close proximity suggest local properties would be affected by operational noise and vibration for either option.

Costs

9.3.17 Construction costs, including risk and optimism bias are set out in Table 26: Non-rail option construction costs and are presented in more detail in Appendix C.

Table 26: Non-rail option construction costs

Option 'family'	Cost
Elevated APM	£177m to £226m depending on route alignment, including risk and optimism bias

Benefits

9.3.18 Given the high level of assessment, the benefits of an elevated APM system are judged to be similar to the sub-surface options, namely:

- Potential demand of between 3,250 and 3,800, including up to 800 international passengers in the morning peak.
- GJT between Old Oak Common and Stratford of around 128 minutes, with a saving of around 12 minutes as against the baseline comparator.

9.4 Elevated travelator and elevated walkway options

9.4.1 The elevated travelator and elevated walkway family of options would link Euston and St Pancras stations by providing passengers with dedicated or upgraded pedestrian facilities for the connection between stations. The options comprise:

- option NRG elevated travelator
- option NRH elevated walkway.

Route

9.4.2 Option NRG is an elevated travelator, east-west along Phoenix Road. A system of elevated travelators at either 200 metres or 300 metres in length would provide a pedestrian route between the two stations. The proposal includes a lobby-style area at high-level on Eversholt

Street for access to Euston Station, with access to the concourse area via escalator. At St Pancras International, a travelator approximately 60 metres in length would carry passengers from Phoenix Road south to the high level Midland Main Line concourse area.

- 9.4.3 An alternative to this is the elevated walkway Option (NRH). The routing and station access arrangements for this option are proposed to be the same as that of elevated travelator option but with a high level walk route only. It is anticipated that journey times for passengers using this route will be equivalent to the baseline comparator walk route between Euston and St Pancras. The baseline comparator walking routes are shown in Figure 21: Baseline comparator walking routes. These options would replace the Phoenix Road element of these with an elevated travelator or elevated walkway.

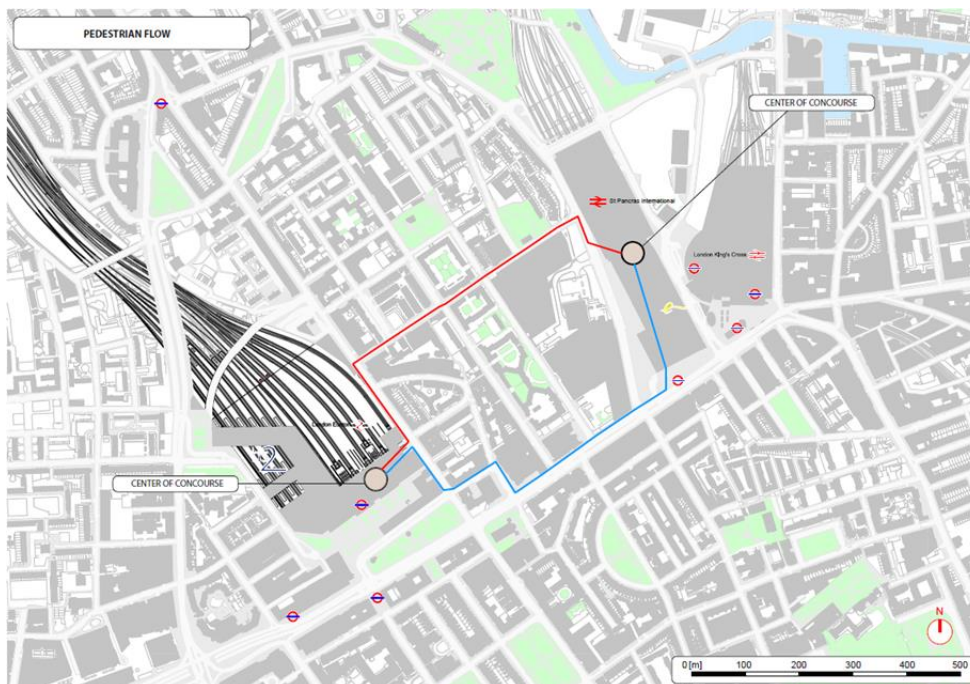


Figure 21: Baseline comparator walking routes

Link operational capacity

- 9.4.4 Assuming a single travelator in each direction, the operational capacity of the elevated travelator system -including allowances for passengers with luggage- would be between 4,200 and 6,000 passengers per hour in each direction. Capacity for both elevated options (with and without travelators) could be impacted by luggage for international passengers, potentially resulting in slower walking speeds that would reduce capacity. The walkway would have to be built with sufficient width to allow for slower-moving passengers with luggage. The link would also need to include a standard walkway for resilience.
- 9.4.5 The elevated walkway option would use similar alignment and station access arrangements. Allowing for two-way operation, a travelator system would need to be around six or seven metres wide and a walkway around four or five metres wide.

- 9.4.6 The travelator option would have capacity and level-of-comfort benefits for passengers compared with the walkway and walk route options.

Rail operation impact

- 9.4.7 The walking route options would have no impact upon the rail operation for HS1 or HS2. We have assumed that timetables would be developed to enable passengers to walk between stations, with enough time spare to make the appropriate onward connection.

Impact on local community

- 9.4.8 Both the elevated travelator and elevated walkway would suffer from a similar degree of visual intrusion as an APM system although the issues associated with construction would be less severe than for an APM.

Costs

- 9.4.9 Construction costs for each of the walk route options are presented in Table 27: Walk-route option construction costs. These do not include risk or optimism bias.

Table 27: Walk-route option construction costs

Option 'family'	Cost
Elevated travelator	£120 million, including risk and optimism bias
Elevated walkway	£85 million, including risk and optimism bias

Benefits

- 9.4.10 Demand for an elevated travelator or elevated walkway is assumed to be similar to demand for an APM system, i.e. up to 800 international passengers during the peak period. The 2010 Route Supplement report concluded that a high level of background demand would be attracted to such a system and that peak hour demand would be likely to significantly exceed the capacity of a travelator. Our review of the potential usage of these options, as set out in section 3, indicates that a travelator option would be expected to provide sufficient capacity.
- 9.4.11 The benefits of a travelator system linking Euston and St Pancras include faster and more convenient connections, which could provide journey opportunities to non-international travellers. The system would be slower than an APM giving a saving of around four minutes as against the baseline comparator. All options would be open to the elements and would not provide a seamless journey.

10 Summary of option assessment

10.1 HS2 appraisal template

- 10.1.1 HS2 Ltd's route development appraisal template provides a template for comparing options. Based on our review of available information for rail and APM/elevated travelator/elevated walkway options, and our high-level assessment of other options, this template can be used to present a comparison of how these schemes perform against the hybrid Bill baseline comparator. The template uses a typical five-scale process to indicate whether the option

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being assessed performs better, worse or similarly to the baseline comparator on the following basis:

---	Major worsening on the comparator scheme
--	Minor worsening on comparator scheme
0	Neutral / no change to comparator scheme
+	Minor improvement on comparator scheme
+++	Major improvement on comparator scheme
N/A	Not applicable

10.2 Summary of assessment

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Option Family		Cost	Construction Feasibility	Operational Capability/ Capacity	Potential Demand (International)	Journey Time Incl. no. of interchanges	Environmental impact	Impacts on other users (Domestic & Local)	Impact on communities	Compatibility with Passive Provision	Custom & Passport requirements	Risks
Baseline Comparator - Hybrid Bill scheme with HS2-HS1 link removed consistent with Secretary of State's Decision												
Rail Options Central & Eastern	Rail tunnel plus shared surface operation	---	---	+	+++	+++	---	---	--	O	+	---
	Rail tunnel plus segregated surface operation	---	---	+++	+++	+++	---	+	---	O	+	---
	Rail tunnel between Old Oak Common and Camden	---	---	+++	+++	+++	---	+	---	O	+	---
	Longer distance Rail Tunnel between Old Oak Common and Stratford or beyond	---	---	+++	+++	+++	---	+	--	O	+	---
Rail Options Alternatives	Euston Cross / Passive Provision	---	---	+++	+++	+++	---	--	---	N/A	O	---
	Kings Cross Tunnels	Reviewed during route selection and not progressed										
	West London Line	Unkown	---	---	+	O	Unkown	---	Unkown	N/A	O	---
	Greengauge 21 Proposals	---	---	+++	+++	+++	---	+	--	O	+	---
APM & Travelator Systems	APM Sub-surface	--	---	+	O	+	--	+++	---	N/A	O	---
	APM Elevated	--	--	+	O	+	---	+++	---	N/A	O	---
	Elevated Travelator/Elevated Walkways	--	--	+	O	+	---	+++	---	N/A	O	---
Enhanced Walk Options at Euston	Use of Crossrail 2 station as walking route	O	O	O	O	O	O	--	O	N/A	O	O
	Enhanced street level walking route	O	O	O	O	O	+	+	+	N/A	O	O

Figure 22: Appraisal summary table

10.2.1 The key conclusions emerging from the review are:

- Enhanced walking routes between Euston and St Pancras would have the lowest cost of all options but would offer no journey time benefits over the baseline comparator. Sympathetic development of these routes could offer potential environmental benefits and possible community and local authority support. This option might overcome a number of cost, feasibility and environmental disadvantages associated with the rail options.
- Crossrail 2 is, at present, an uncommitted scheme, although it would provide a link between Euston and St Pancras. There would be no journey time benefits and the use of Crossrail 2 platforms as a through-route for international passengers is unlikely to be acceptable to TfL.
- All rail solutions provide significant journey time savings but have high construction costs of between £610 million and £6,000 million. All also suffer from significant operational and environmental disbenefits. Most of the rail schemes reviewed have been previously rejected. Work by HS2 Ltd has indicated that the hybrid Bill (NLL Enhanced) option had a construction cost of £610 million and would not offer good value for money based on internal DfT analysis. All other rail options will have higher construction costs than this option, with similar benefits.
- On the basis of this review, there is no viable rail option capable of meeting the strategic aspirations whilst successfully addressing stakeholder concerns and value-for-money criteria.
- Passive provision has been suggested in a number of petitions to the hybrid Bill and would allow for any of the rail options to be deferred to a later date. Construction costs have been estimated at either £42 million or £103 million depending on the exact nature of passive provision provided. Although protecting the future potential delivery of a high-capacity link at a later date, when the economic case might be stronger, passive provision would also defer disbenefits associated with the rail options. Construction of the link at a later date would require the removal of all excavated materials from the tunnel portal in Camden and would result in increased cost and environmental/social impacts.
- APM and elevated travelator/elevated walkway options aim to integrate travel between Euston and St Pancras in a manner similar to an airport terminal. Journey time savings over the baseline comparator are around 12 minutes. Costs for a scheme of this type are significantly less expensive than rail options but still have construction costs of £200 million or more. Whilst potential users include a high volume of local pedestrian traffic, the impact of these proposals on the local community remains highly contentious given the dense fabric of the local area. Options for tunnelled systems have major impacts during construction and elevated systems have major visual intrusion issues during operation.

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- Petition items include a West London Line option which shows a major worsening across most criteria with no improvement in GJT over the baseline. It could provide benefits to other users, but to the detriment of separating international and other passengers.