High Speed Rail
London to the West Midlands and Beyond

A Report to Government
by High Speed Two Limited

PART 5 of 11

Further copies of this report can be obtained from www.hs2.org.uk.

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Unless specified, all maps, tables, diagrams and graphs in this report are a product of HS2 and its consultants.

Chapter 1:
ICE 3 high speed train on the Frankfurt-Cologne high-speed rail line, Sebastian Terfloth;
Eurostar, Dave Bushell www.canbush.com/ppbfrontpage.htm;
Gümmenen viaduct over the river Sarine with TGV 9288, Berne, Switzerland, Chriusha;
Tunnelling, HS1 Ltd
AVE Tarragona-Madrid, Fototrenes
St. Pancras Station, HS1 Ltd

Chapter 5:
Matisa www.matisa.com/matisa_ang/matisa_produits.html

3.4 Intermediate stations

3.4.1 Before describing the potential routes between London and the West Midlands, we set out here our findings on the potential for an intermediate station. We have just discussed the case for a station on the outskirts of London (serving Heathrow) and will do the same for an interchange near Birmingham later in the report. In contrast this section focuses on the potential for an additional station between those major conurbations.

The implications of an intermediate station

3.4.2 As with interchange stations, an intermediate station on the line of route can extend the benefits of high speed rail by broadening the overall market it serves. The additional market would also be wholly separate from the market served by stations at either end of the line of route in contrast to an interchange station on the city outskirts, the market for which inevitably overlaps with its city centre terminal. For passengers served by an intermediate station there could be significant benefits from shorter journey times and increased capacity (through both relief from crowding and a more frequent service).

3.4.3 Typically however, high speed rail lines in other countries have not included intermediate stations on open route sections, for a number of reasons.

- **Journey times.** Intermediate stations result in journey time penalties for through passengers. In the case of an intermediate station on the line of route, these penalties are accentuated because the train would be slowing from top speed, before then accelerating back to it after stopping. From top speed the time penalty for stopping would be up to 5 minutes.
- **Inefficient use of capacity.** To serve an intermediate station in the middle of the line of route implies that certain trains would run from their original destination with a sufficient number of empty seats to allow passengers at the intermediate station to board the train. This would be an inefficient use of capacity when demand from larger destinations elsewhere on a network means that train paths are highly prized and the trains can be filled up there.
- **Impacts on capacity.** On the main line, stopping a train at an intermediate station can have a dramatic effect on the number of available train paths, unless all trains stop on a consistent basis. Intermediate stations other than on the edge of conurbations rarely provide a sufficient market to justify the stopping of all high speed trains; and to allow a limited number of trains to stop at an intermediate station requires additional lanes alongside the main route, so that stopping trains can decelerate on their way into the station, stop, and then accelerate again to rejoin the line.

  Nevertheless, there is still an impact on capacity. A gap must be created in the pattern of paths to allow the train to rejoin the main line and then, as the train accelerates back up to top speed, it takes up further capacity by once more holding up the progress of a non-stop train behind it. This can only be overcome by choosing to stop that subsequent train at the intermediate station also.

  On a core trunk section of route, where train paths are fully utilised, this impact can considerably reduce the line's overall capacity and the paths taken up to achieve this stop will be paths which might otherwise have served principal city destinations (with their associated benefits) elsewhere.

3.4.4 Many of these implications have particular significance for HS2, which would act as a trunk route both on Day One and for the longer term high speed network. Our remit dictated that an intermediate station should only be included as part of the HS2 scheme if it was not detrimental to the overall business case. In the rest of this section we describe our process of investigation.

Passenger demand

3.4.5 We considered the potential demand for high speed rail from twelve of the largest population centres in the London to West Midlands corridor.

Location	No. of rail trips to/from London 2004
Aylesbury Vale	0.8m
Bicester	0.6m
Banbury	0.6m
Milton Keynes	2.1m
Coventry	0.7m
Rugby	0.5m
Warwick	0.8m
Luton	3.3m
Kettering	0.5m
Bedford	1.8m
Northampton	1.9m
Oxford	1.5m

Figure 3.4a Number of rail trips between London and intermediate locations in 2004

3.4.6 As Figure 3.4a demonstrates, there is considerable scope for demand on HS2 from several population centres within the potential corridor for HS2. The focus of this demand is commuting trips into London, and in a number of locations there would be considerable time savings – which would lead to strong benefits as well as potential demand growth.

3.4.7 We selected three possible locations, Aylesbury, Milton Keynes and Bicester (which could also serve the Oxford market), that looked to be the best options in terms of demand and potential journey time savings and which were on our shortlisted lines of route. The conclusions below will hold for any intermediate station. Of these stations, Milton Keynes offered the largest potential market but less scope for time savings and greater competition from classic rail services – particularly with the potential for released capacity. Bicester and Aylesbury had the greatest potential time savings, and therefore the greatest potential for growth in demand.

Impact on passengers using intermediate stations

3.4.8 The three stations were modelled assuming they were served by three trains per hour, no premium fares and a train capacity of 1,000 seats. It was clear from this modelling that a station at either Bicester (serving Oxford) or Milton Keynes could generate significant benefits to passengers in the vicinity of the intermediate station. The scope for benefits around Aylesbury was more limited.

3.4.9 Figure 3.4b shows that Milton Keynes would generate demand in 2033 of almost 9,000 passengers in the morning peak three hours. This would mean virtually all of the capacity was used up in this period. At Bicester just over 6,000 passengers would use the station in the morning peak, with around two thirds of seat capacity filled.

		Aylesbury	Milton Keynes	Bicester
Demand in 2033 (passengers in am peak only)		1950	8700	6400
Passenger benefits from intermediate station (PV 2009)				
Am Peak Hours	User Benefits	140	510	640
	Revenue	-1	360	300
All Day	User Benefits	630	2590	3390
	Revenue	-110	1600	1500

Figure 3.4b Passenger volumes and transport user benefits from high speed rail at intermediate locations, excluding impacts on other HS2 passengers

3.4.10 The benefits to passengers from these stations would also be significant, with both time savings and relief of crowding on the classic network. These could amount to £500-600m during the peak hours, rising to £2.6-3.4bn if services continued throughout the day. The revenues of an all day service would also pay for the additional capital costs of an intermediate station at Milton Keynes or Bicester (estimated to be in the region of £150m).

3.4.11 However the benefits outlined in Figure 3.4b only consider the impacts on people who use the intermediate station. This ignores the wider impact on other HS2 passengers, which must be considered before deciding whether an intermediate station could add to the business case.

Impacts on other HS2 passengers and costs

3.4.12 Passengers not using the intermediate station would experience a longer journey –over 5 minutes by the time a train decelerated, stopped and accelerated again. To give an indication of the size of this penalty, stopping a train with 500 passengers would reduce benefits by over £8m (PV). So stopping three trains per hour in each direction throughout the day would represent a cost of almost £800m.

3.4.13 This is not in itself sufficient to outweigh the benefits of the intermediate station. However two further arguments suggest an intermediate station is unlikely to add to the HS2 business case:

- The trains running on HS2 are unlikely to have spare seats when they reach an intermediate station, particularly during the peak hour. Given the level of demand forecast, this would either result in severe crowding on trains south of the intermediate station, or would require additional trains to be run (for which there is insufficient track capacity).
- Stopping at the intermediate station would result in the loss of up to 1 train path. So to stop three trains in each direction over the course of an hour, this would reduce capacity by around 20% on the most congested section of the line.

3.4.14 This latter point is of particular importance. In choosing the destinations the high speed line ought to serve, it is necessary to review not only Day One but the potential future network. The loss of capacity would in effect rule out extending a high speed network to serve Leeds and places beyond, unless a second trunk were built to London. Chapter 6 is clear on the benefits of serving major cities, which would generate benefits significantly in excess of those provided by an intermediate station. In this context we do not believe an intermediate station would add to the business case for HS2 in the long term.

Summary and key recommendations

3.4.15 An intermediate station at Bicester (serving Oxford) or Milton Keynes could generate significant benefits to users of the station. However, the case for an intermediate station also depends critically on the impacts this would have on other HS2 passengers and the capacity of the line.

3.4.16 We found that even with wider economic benefits, including any from regeneration, an intermediate station would be detrimental to the HS2 business case unless a loss of other services on the line could be avoided. This would not be achievable.

3.4.17 We therefore recommend that an intermediate station is not included in the HS2 scheme.

3.5 Routes between London and the West Midlands

Introduction

3.5.1 We set out below how we arrived at our proposed route from Old Oak Common to the outskirts of Birmingham. More detail can be found in the AoS and Route Engineering Study – including plan and profile drawings for the preferred and alternative routes.

Creation of the long list and determining the short list – Stage One and Stage Two

3.5.2 To produce our long list of options we started with the principle of following existing transport corridors, for example the M40. Bearing in mind our minimum limits of curvature to maintain high speed and recognising the impracticalities of building through centres of population, including small clusters of housing or environmentally sensitive areas, we sought out possible routes linking the two conurbations.

3.5.3 Figure 3.5a shows how we started out with many different route options. In order to evaluate the routes and make decisions we carried out comparisons between options – known as 'pairwise comparisons'. To do this we divided the long routes into route sections. We were then able to make comparisons on these shorter sections to clearly understand the different implications of choosing one over another.

3.5.4 As there are fewer distinguishing features for lines of route than between our long list of stations, we started with the more detailed criteria to narrow down the long list:

- Engineering and construction feasibility.
- Costs – based on an initial evaluation of the high-level scope with a generic unit rate applied to different types of route, for example tunnels and open sections.
- Environmental, social and spatial considerations – simplified sustainability framework.
- Demand – any relevant demand assessment mainly focused on journey time benefits.

3.5.5 The lines coloured dark grey in Figure 3.5a are those routes that we decided not to pursue at that stage. The pairwise analysis demonstrated that the construction of these route sections would have resulted in a longer journey times than those provided by the alternatives. The sustainability assessment indicated that these routes were no better than the remaining routes and in some places were significantly worse.

3.5.6 It is important to highlight the reasons why we decided not to pursue the two most easterly options just north of London as these are the only two options that would avoid the Chilterns Area of Outstanding Natural Beauty (AONB). As these routes continue further north they are substantially longer than the other alternatives under consideration at the time and would require either substantial tunnelling to avoid major population centres (particularly Luton) or could have resulted in significantly more potential demolitions than the routes taken forward for further appraisal. They would also result in longer journey times than the other routes under consideration at the time (about ten minutes if they go via Old Oak Common which is in our preferred package).

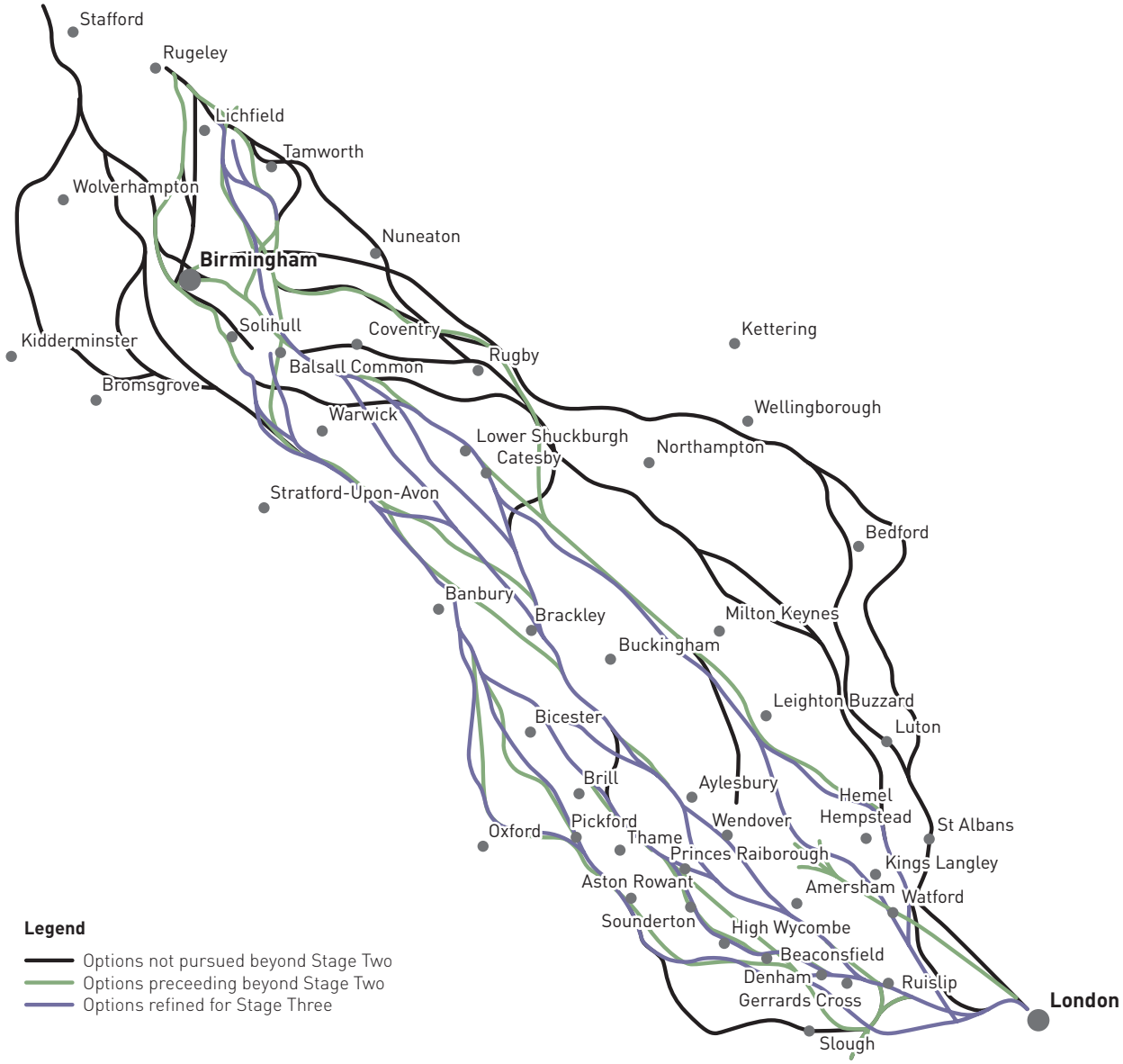

Figure 3.5a Long list of routes considered between London and the West Midlands

Selecting the preferred and alternative options – Stage Three

3.5.7 We continued to optimise those routes shown in green and blue in Figure 3.5a to improve journey times, better adapt the route alignment to the topology of the land, avoid environmental and sustainability features and, where possible, minimise the requirement for substantial land take and demolitions. Whereas at Stage One we had compared sections of route alignment running through similar areas to decide which were comparably weaker, we now turned to comparing whole route lengths. Consideration of the route through the Chilterns was particularly important in our decisions.

Options through and round the Chilterns

The most direct route between London and Birmingham follows a north-westerly direction, going through the Chilterns AONB. This is an area of extensive beech woodland, scattered villages and farmsteads, contrasting intimate valleys with more open valleys and extensive views. We paid particular attention to route investigation here, seeking to strike a balance between minimising the impacts on the AONB with the engineering requirements for a high speed railway and cost.

Initially we identified six main corridors through the Chilterns:

M40 corridor: This would form part of **route 1**. The M40 passes through comparatively hilly terrain, requiring much of the HS2 route to be in tunnel or on viaduct. A largely surface route through rural land in the AONB to the southwest of M40 was also considered, but this would be longer and take the route closer to the Cotswolds AONB. Variants and combinations of these routes were considered but none improved the relative performance of these route options compared to others under consideration, particularly in terms of potential sustainability impacts.

Chiltern Line corridor via High Wycombe: We tested a surface alignment in this corridor, as part of **route 2**. We concluded it was not viable as it would require a large number of residential and commercial property demolitions, and many properties would be affected by noise. A longer alignment in tunnel was considered feasible but more expensive and would introduce a very large number of properties to the risk of ground-borne noise and vibration.

A413 arterial valley: This offered a long broad valley across the Chilterns between the Chalfonts and Wendover that would, through a combination of tunnelling and surface alignment, provide a route that was both economical and performed well as a high-speed railway. The route would cross a greater length of the AONB but the alignment would be largely hidden either in tunnel or deep cutting to the north of the A413 between Amersham and Little Missenden, or shallower cutting to the north before meeting the A413 and Chiltern Line corridor. Fewer properties would be directly affected by the route or receive noise from the route's operation because of tunnelling and positioning to avoid settlements. This option was carried forward as part of **route 3**.

Options through and round the Chilterns *continued*

WCML corridor: This would provide a shorter route across the AONB but would need to be served by a very long tunnel alignment from London. The nature of the long tunnel carries with it certain limitations, for example emergency exits at relatively regular intervals every 2km. This option was carried forward as part of **route 4**.

M1 corridor: This provided a more northerly and less direct route for HS2 between London and Birmingham. Northerly variants via Luton and Northampton were not pursued because of the greater length of route and large numbers of property demolitions associated with required land take. A route skirting the north of Hemel Hempstead was considered but provided a less favourable railway alignment; it would also have affected aspirations for future development to the west of Hemel Hempstead and crossed a greater length of the AONB than the WCML corridor, which became the favoured northerly route.

Midland Main Line (MML) corridor: The MML corridor also connected a very long tunnel from London but provided the most northerly alignment and least direct route for HS2 between London and Birmingham. The alignment would exit London in tunnel, surfacing near St. Albans. Impacts on properties were expected to be considerable. The route passed around Luton and the north and east of Northampton, before continuing on to Coventry/Kenilworth. Noise and severance impacts on a number of rural villages were considered to be significant. Two sub-alignments; one through, and one to the east of Luton were considered. Both were considered inferior, based on potential demolitions through required land take and impacts on SSSIs and heritage features.

Subsequently, we investigated hybrid routes between the Chiltern Line Corridor and the A413 arterial valley. These consisted of a variety of tunnels and surface alignments to overcome direct effects on settlements, negotiate difficult topography and keep any surface alignment across the AONB to a practicable minimum. A route between Gerrards Cross and Princes Risborough was developed and taken forward as **route 2.5**.

3.5.8 We started with a consideration of four routes. Following further work we decided not to pursue routes 1 and 2, for the reasons stated below. As part of that work we devised a new route – 2.5. We then compared this with routes 3 and 4 to reach conclusions about our preferred and alternative routes.

Route 1 – not pursued

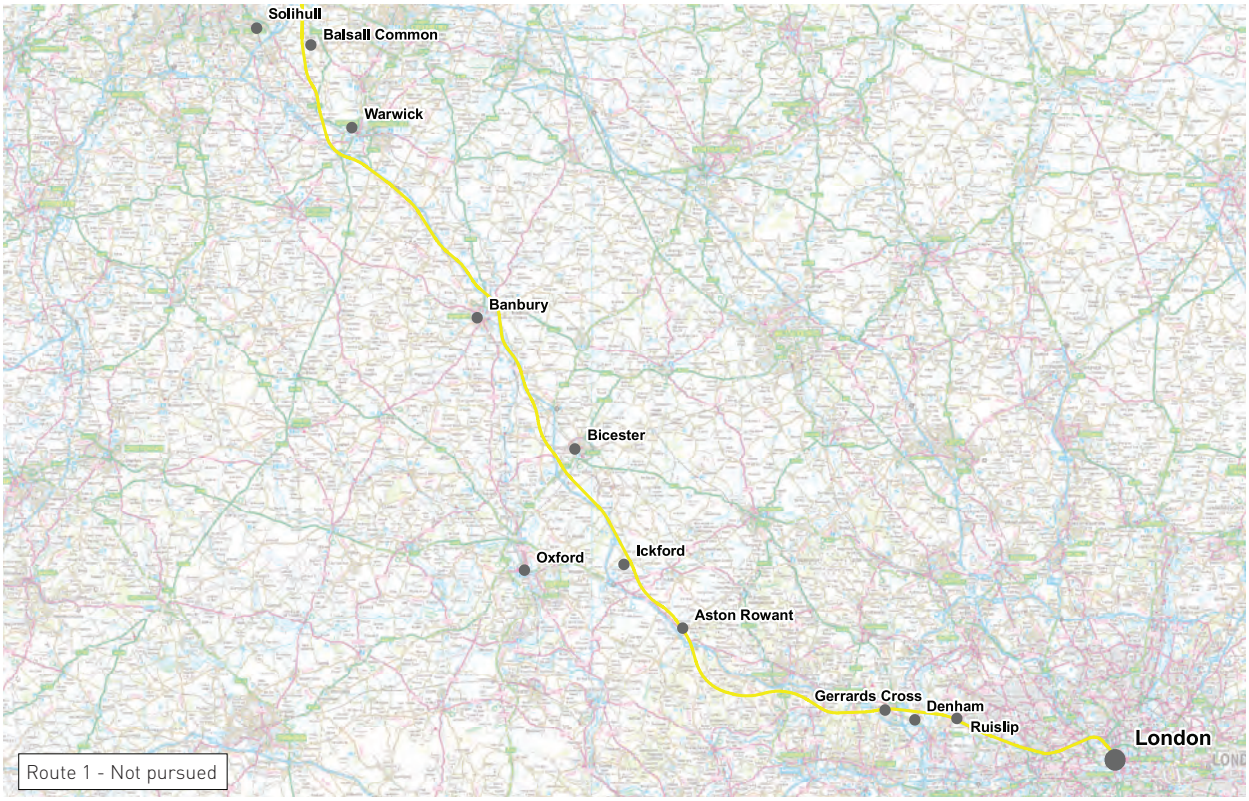

Figure 3.5b Route 1 – not pursued

3.5.9 From Old Oak Common, this route would follow a 13 km section of widened route corridor, following the existing railway line. From Denham the route would enter a series of 11 tunnels and 15 viaducts before reaching the northern edge of the Chilterns at Aston Rowant. The line would then take a surface level route until it reaches a tunnel and a viaduct near Ickford. From the Ickford viaduct it would continue on open sections until a 4.25km tunnel. The route would then take either a surface alignment or viaducts to reach Balsall Common, where it would meet the other routes.

3.5.10 This route had a longer journey time and cost more than the other routes. After West Ruislip the amount of disruption caused by construction would be comparatively low except for properties in Denham and Gerrards Cross that would be affected by tunnel construction, and the associated settlement effects.

3.5.11 We found it had major adverse impacts on landscape, biodiversity and water resources and performed least well in comparison to the other options. It would pass at the surface through 14.5km of the Area of Outstanding Natural Beauty, as well as passing close by the Cotswold AONB for some 9km. Its effects on biodiversity derive from potential indirect adverse impacts (via hydrological change due to tunnelling) on the Aston Rowant Special Area of Conservation (SAC). It would also potentially require diversion of up to 1km of the River Blythe at the West Midlands end, as well as possible multiple river crossings. There would be scope to mitigate water and ecological impacts, but less so for landscape impacts. This route would result in more substantial impacts to people and the communities through which it passes, particularly from operational noise and vibration, demolitions and potential community severance. On this basis we did not pursue it any further.

Route 2 – not pursued

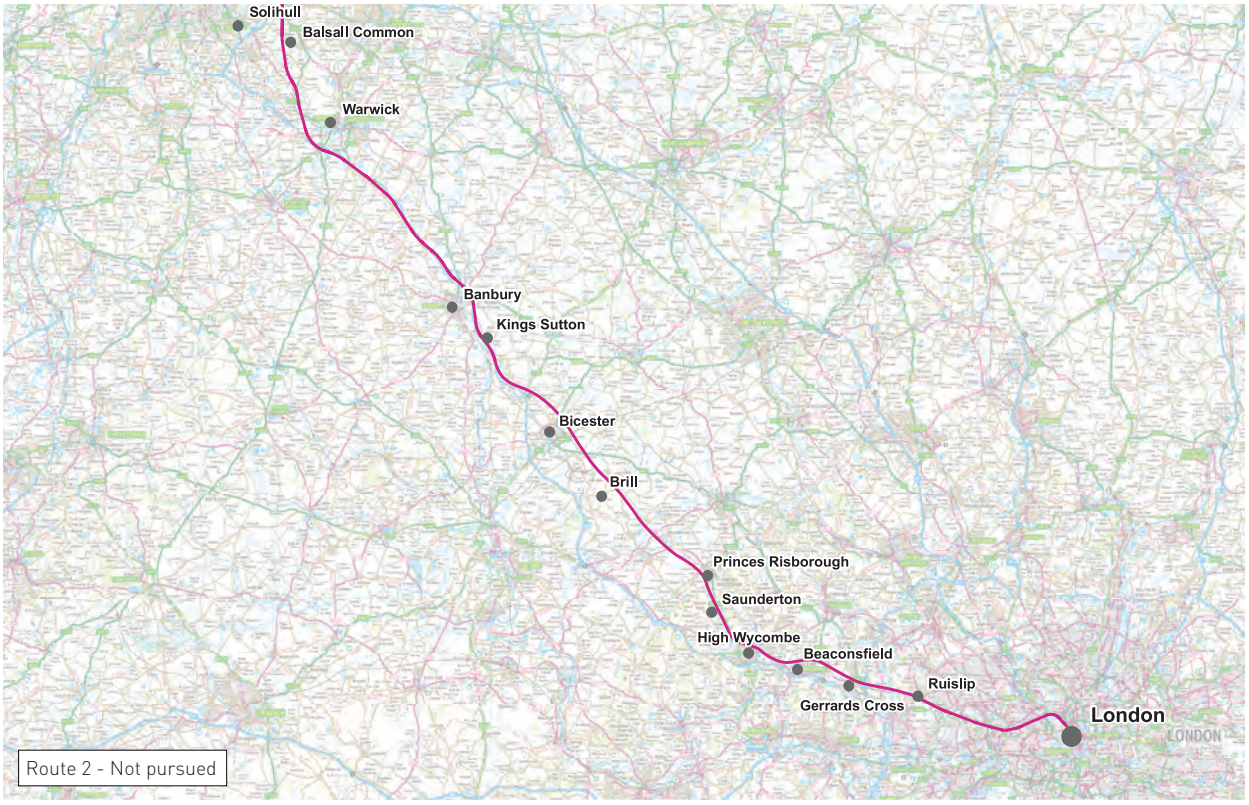

Figure 3.5c Route 2 – not pursued

3.5.12 This route would follow the same path as route 1 until just west of West Ruislip where it would take a more northerly route. From West Ruislip the route would follow the Chiltern Lines descending into a 2km tunnel at Gerrards Cross and others at Beaconsfield, High Wycombe and Saunderton. After leaving the Chilterns the route would pass over viaducts and through one tunnel near Brill. The majority of the rest of the route is at the surface until it re-joins route 1 near Kings Sutton.

3.5.13 Following analysis of route 2 we decided that the southern section of the route, before it joins with route 1 north of Bicester, was worth pursuing given it had a relatively short surface route of around 8km through the Chilterns AONB and provided a relatively close route for serving Heathrow in the future. With further design and engineering work, in conjunction with the sustainability team, there was also potential for a further reduction of the assessed noise and community impacts. To explore whether route 2 could be achieve a further improvement in terms of journey times and costs, we decided to create a route 2.5. This linked the southern most part of route 2 with the northern part of route 3. We did no further work on the northerly part of route 2.

Preferred and alternative routes

3.5.14 After deciding not to pursue routes 1 and 2 and after further optimisation work, we chose the preferred and alternative routes which we describe below. We produced plan and profile maps for these three routes which have been submitted alongside this report. Figure 3.5d illustrates the main cost and journey time differences between these whole routes.

	Route 3	Route 2.5	Route 4
Journey time*	44min 09s	45min 47s	45min 43s
Length (km)	174.88km	179.07km	176.70km
Cost (Base Cost – without risk) (£bn)**	3.72	4.31	5.08
Amount of tunnelling (km)	20.25	27.52	39.5

* Includes time for stopping at Old Oak Common

** Each route includes all line of route links from Euston to a common point near Birmingham; all station costs excluded.

Figure 3.5d Comparative assessment of route options

Route 3 – preferred route

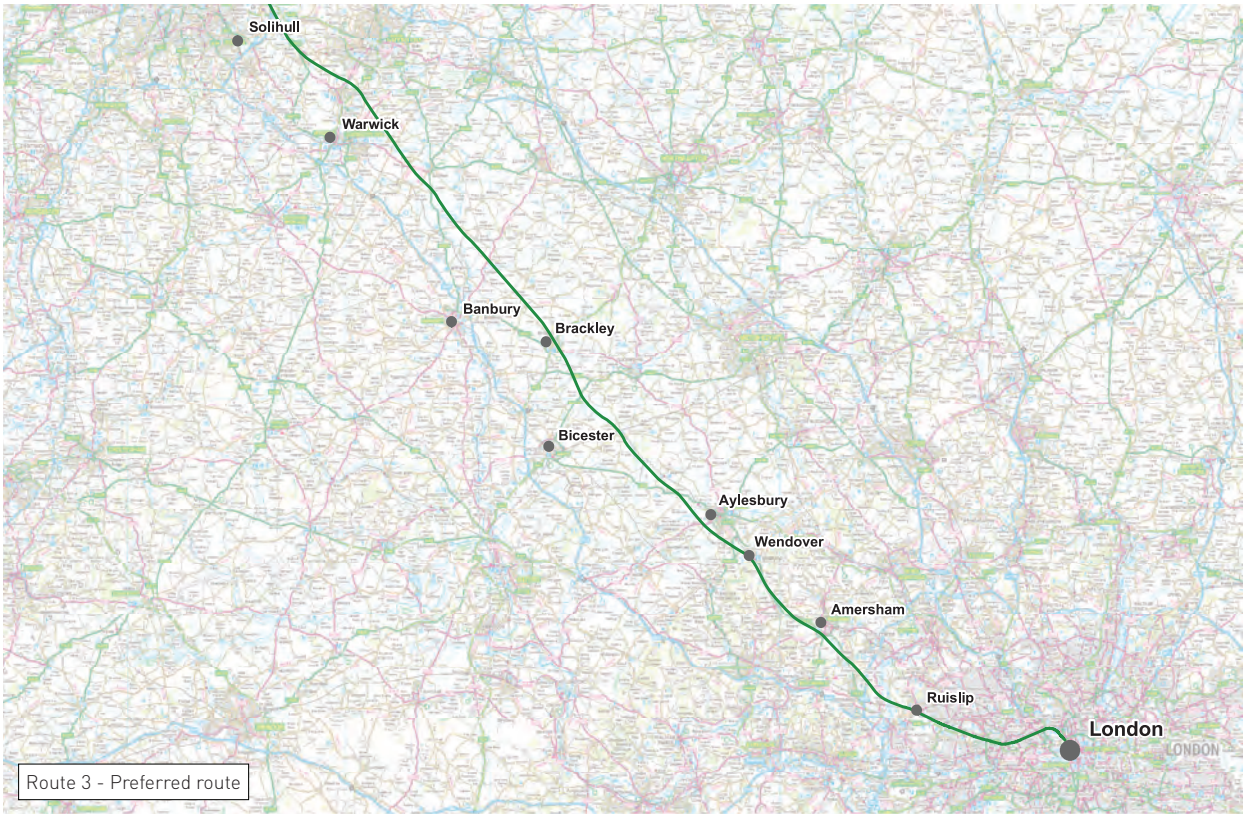

Figure 3.5e Route 3 – the preferred route

Design and construction

3.5.15 From Old Oak Common the route would follow the same 13 km section of a widened Chiltern route corridor as routes 1, 2 and 2.5. This would require works to the adjacent Chiltern Lines infrastructure to accommodate HS2 as well as low retaining walls to support the boundaries of the enlarged route corridor. Subject to more detailed design, there might be some temporary impact on Chiltern line services during construction. From West Ruislip the route passes over a 3.6km long viaduct to reach the M25. Just before the motorway it would pass into 9.6km tunnels before surfacing in deep cutting north of Amersham Old Town. At this point the route would climb up the side of the valley in cutting for just over 2km before entering a 1km tunnel. After this tunnel, the route would climb in cutting, levelling out near the top of a ridge after 3km.

3.5.16 The route would continue in cutting close to the top of the ridge before beginning its descent towards Wendover on a 450m viaduct. Just before Wendover the route would cross the A413 road and the Chiltern Line Railway on a 600m viaduct, then pass Wendover on the surface before continuing towards Aylesbury on a low 3.8 km viaduct crossing a flood plain. It would pass Aylesbury before entering a 33km stretch of countryside, largely on the surface where the alignment follows close to the former route of the Great Central Railway until Brackley. At this point the route topography becomes hillier, though no major structures would be required until west of Southam and east of Warwick where a 4km viaduct would cross a flood plain. Shortly afterwards a short tunnel would be needed to pass under the Ufton Wood/Long Itchington Wood SSSI. A few kilometres further on the alignment would pass through Stoneleigh Park and Gardens before passing between Kenilworth and Coventry. It would then pass over the WCML at Berkswell before running close to the A452 to head to a location east of the National Exhibition Centre.

Environment and sustainability

3.5.17 Compared to routes 2.5 and 4, this has the longest surface section through the Chilterns, although it was considered to have less impact on a range of other features including communities, accessibility (including impacts on access to footpaths and nature trails), sites designated for ecological purposes such as SSSIs and ground borne noise impacts. Mitigation of the landscape impacts on the Chilterns AONB has been incorporated by tunnelling certain sections of the route alignment (around 32% of the route through the Chilterns AONB is in tunnel in the current plans), by following an existing route corridor as closely as possible (around 37% of the route follows existing route corridors including the A413), and by keeping the remaining sections of the route on the surface, minimising the length of possible viaducts and ensuring the route could be set down in the landscape in cutting and screened with vegetation and embankments wherever possible.

3.5.18 From Aylesbury north this route presents few significant impacts on communities and key environmental features, although there are some key water resources and noise attenuation considerations which would need to be explored at subsequent stages of any HS2 proposals and analysis.

Route 2.5 – preferred alternative

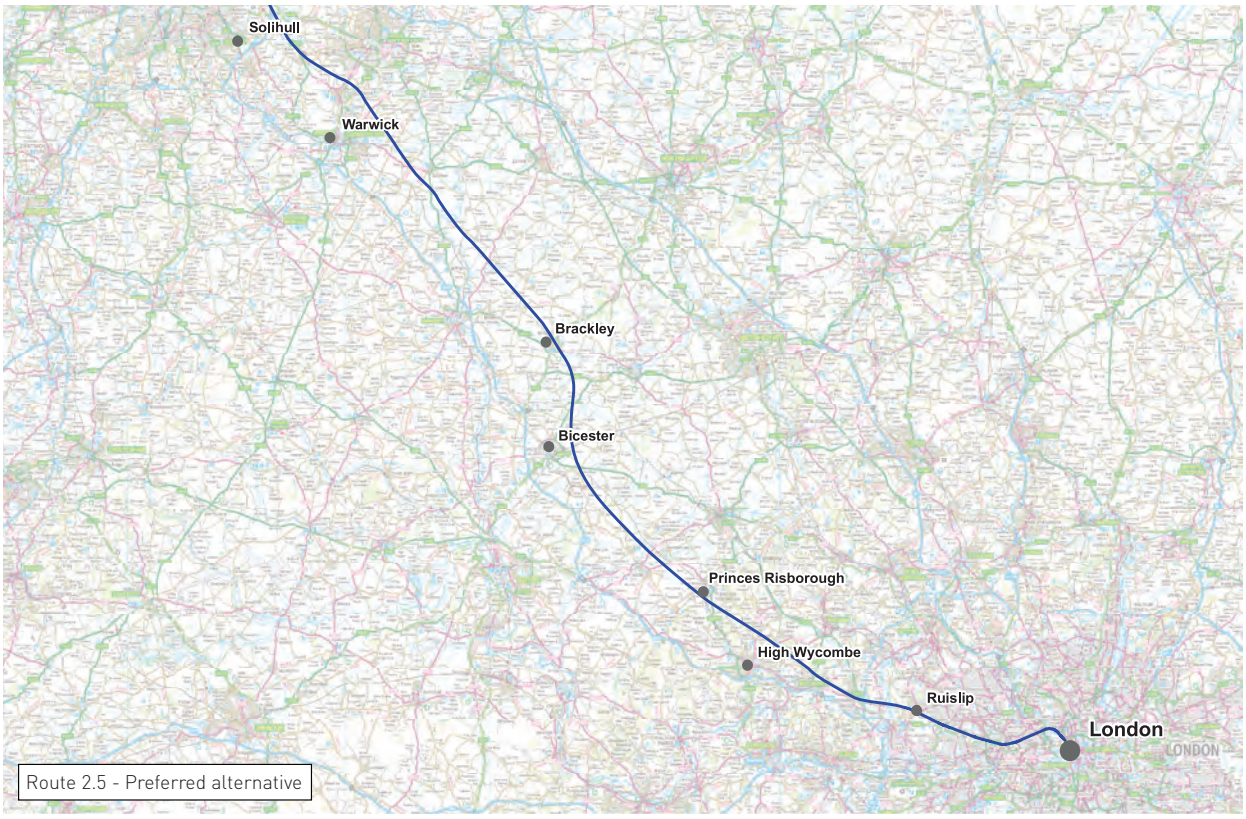

Figure 3.5f Route 2.5 – the preferred alternative route

3.5.19 From Old Oak Common this route would follow the same 13 km section of widened Chiltern route corridor as route 3 until West Ruislip. At this point it would continue running adjacent to the Chiltern Lines (whereas route 3 diverges to the north), and would then continue running beside the Chiltern Lines until Denham where it would enter a 4km tunnel passing beneath Gerrards Cross. West of Gerrards Cross it would pass over undulating ground with a series of cuttings and embankments and viaducts. It would then enter another tunnel to pass beneath Hazlemere, emerging at Hughenden where the route would pass over a 720m viaduct crossing the valley before continuing into a further 8.4 km tunnel. This would emerge about 1km west of Princes Risborough. From then on the route would continue on the surface through open countryside passing to the west of Haddenham until Dorton and Brill where it would enter 2 short (590m and 410m) tunnels. Thereafter the route would continue on more gently rolling open countryside for a distance of 21 km, crossing 2 major viaducts of 1160m and 635m before joining route 3.

3.5.20 Key sustainability impacts associated with this route include noise impacts, particularly ground borne noise and vibration effects associated with tunnelled sections, increased spoil disposal arising from longer tunnelled sections of route, and community impacts through required land take and potential demolitions.

Route 4 – alternative

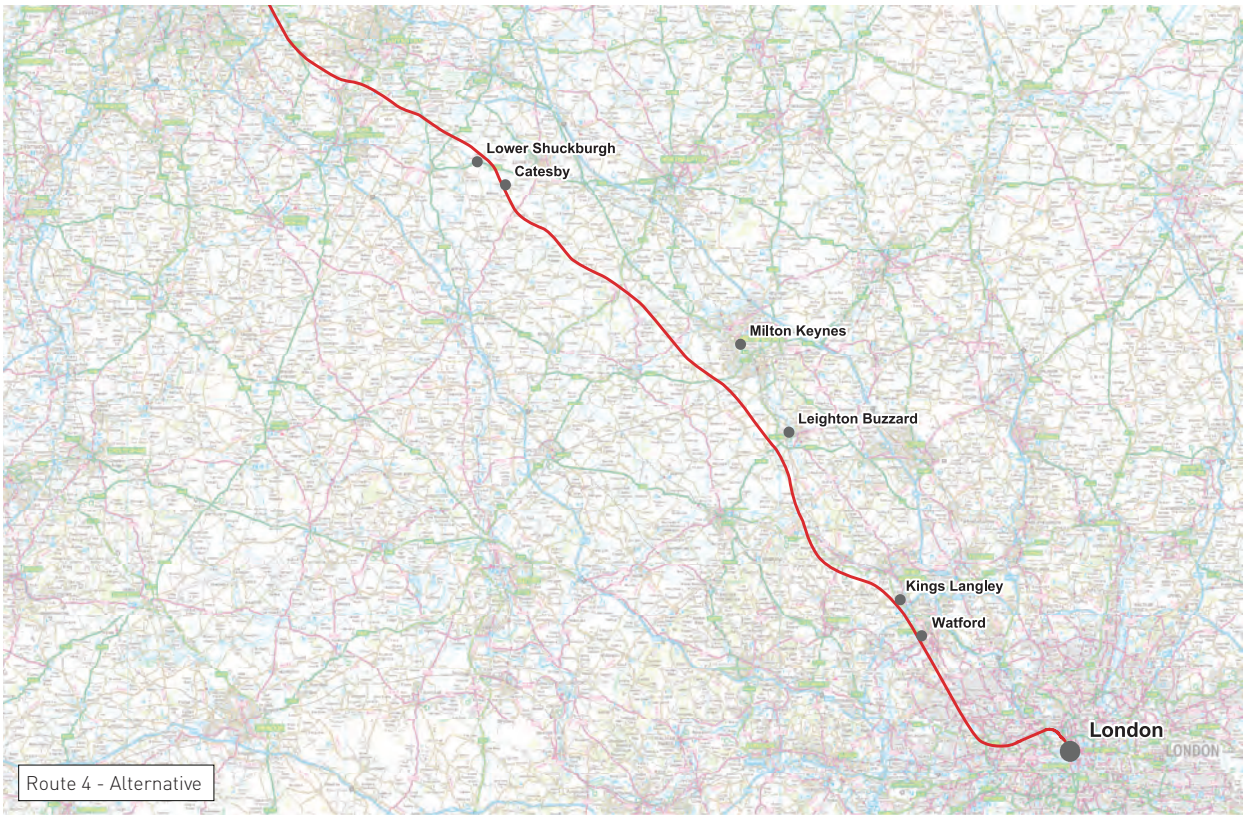

Figure 3.5g Route 4 – a further alternative route

3.5.21 From Old Oak Common the route would turn right to go in a northerly direction in 28km of twin bore tunnels, to emerge at a portal at Kings Langley, just outside the M25. Apart from this tunnel and two others at Catesby and Lower Shuckburgh there would be a relatively low number of structures on this route.

3.5.22 Route 4 would have the shortest section of these three routes through the Chilterns and moderate impacts on communities and environmental features along its full route. As with route 2.5, when compared with route 3, it would have greater potential adverse impacts for biodiversity, vibration and community integrity.

3.5.23 Route 4 would be significantly more expensive and offer a longer journey time than route 3. In addition if a direct link to serve Heathrow was required, via a spur or a loop, this would be very much longer, and would itself traverse sections of the Chilterns, and cost in the region of £4-5bn.

Summary and key recommendations

3.5.24 We considered a wide range of routes between the outskirts of London and Birmingham, covering an area broadly bounded by the M1 and M40. We paid particular attention to routes through the Chilterns. We have identified three feasible routes. Our conclusions and recommendations regarding these are:

- We recommend route 3 – which follows the A413 corridor across the Chilterns, partly in tunnel – for inclusion in our preferred scheme. This route is somewhat better than the next best route on cost and journey time, and no worse on sustainability grounds.
- Route 2.5 - which follows the Chiltern corridor via Beaconsfield, with a larger proportion in tunnel - is slightly inferior overall, but there is a genuine choice to be made here.
- Route 4 – which follows the WCML corridor through the Chilterns – has significantly higher cost and a longer journey time than route 3, but offers the shortest route through the AONB. A direct link to Heathrow from this route is likely to be prohibitively expensive.
- Further optimisation should be undertaken. There is potential to avoid and mitigate further some of the key impacts of all these routes.