

HS2 railway, UK: route optioneering

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The company HS2 Ltd was set up by the UK government in January 2009 with an initial brief to report on options for High Speed Two, a high-speed railway between London and the West Midlands. This was to include access to London and Birmingham city centres, but with the potential for future extension northwards. Options were also required for intermediate stations and connections to the Great Western main line, the Elizabeth line and High Speed 1. From the outset the Department for Transport and HS2 Ltd applied government business case methodology for preparing and assessing proposals in order to derive the best scheme and to be able to justify the choices during the consultation and approval process. An 'initial preferred route' was published in 2010 and, following modification, there was a national public consultation in 2011. The hybrid bill for phase 1 was deposited in November 2013 and royal assent was obtained in February 2017. Throughout, a rigorous process of longlisting possible options, shortlisting and selection was adopted. At each stage the proposals became more detailed as the route, design and mitigations were developed. Consequently, the selection criteria, costing and evaluation also became more detailed and specific.

1. Introduction

This paper explains how the phase 1 scheme for the UK's High Speed Two (HS2) north-south railway was determined. Work commenced on planning the route and station locations in January 2009 when High Speed Two (HS2) Limited, the government-sponsored company responsible for developing and promoting it, was set up. The initial brief was to report on options for a route between London and the West Midlands including access to London and Birmingham city centres, but with the potential for future extension to Greater Manchester, West Yorkshire, the North-east and Scotland. Options were also required for intermediate stations and connections to the Great Western main line, the Elizabeth line and High Speed 1.

Since 2009, numerous options for each element of the route have been identified, explored and assessed. Preliminary conclusions were subjected to consultation, refinement and where necessary reviewed. In this way the proposed scheme was developed and the environmental impacts assessed. In each case any necessary modifications were made and mitigations incorporated before inclusion in the hybrid bill and eventually the High Speed Rail (London-West Midlands) Act 2017 ('the HS2 Act').

2. The HS2 phase 1 scheme

The HS2 phase 1 railway that evolved from the option-selection process comprises a 225 km route from London to Birmingham and to the West Coast main line north of Lichfield, with four stations – two city centre termini at London Euston and Birmingham Curzon Street and two intermediate stations. These are Old Oak Common in west London, which will provide an interchange with the Great Western main line, the Elizabeth line and Heathrow Express, and Birmingham Interchange to the east of Birmingham International airport and the National Exhibition Centre, which was planned as a parkway station and will serve a wide area of the West Midlands including Solihull, the east side of Birmingham, Coventry and the adjacent towns.

The phase 1 route is shown in Figure 1. It will run almost entirely in tunnel through London to West Ruislip, where it will cross the Colne Valley on a viaduct before entering another tunnel through most of the Chilterns area of outstanding natural beauty (AONB). The route to the West Midlands follows a more-or-less straight line from the Colne Valley through the gap between Kenilworth and Coventry to Birmingham Interchange, passing north of Denham and west of Amersham, Wendover and Aylesbury and east of Brackley. From there it runs through the M42 corridor to Curdworth, then north-east around Lichfield to connect to the West Coast main line at Handsacre. Provision is made at Curdworth and Handsacre for future extensions to Leeds and Manchester. At Water Orton there will be a delta junction for the spur to Curzon Street in central Birmingham that runs along the M6 corridor and is partly in tunnel through Bromford.

Avoiding and mitigating the environmental effects has been a central pre-occupation in planning and developing the scheme from the outset. At many places along the route the alignment was modified to minimise effects on locally sensitive areas, sometimes several times. Once the alignment was determined, mitigation measures were added on a scale commensurate with the scale of the project. Among other things

- nearly a quarter of the route is in tunnel
- on three-quarters of the surface route (at all the locations where it is necessary), adjacent areas will be protected from noise nuisance by cuttings, earthworks, or barriers
- comprehensive air quality measures have been applied that are more stringent than for any other major project
- 650 ha of new and replanted woodland will be provided to replace the 310 ha lost – a total of 7 million trees will be planted as part of the scheme
- the project will create the largest archaeological opportunity ever in the UK

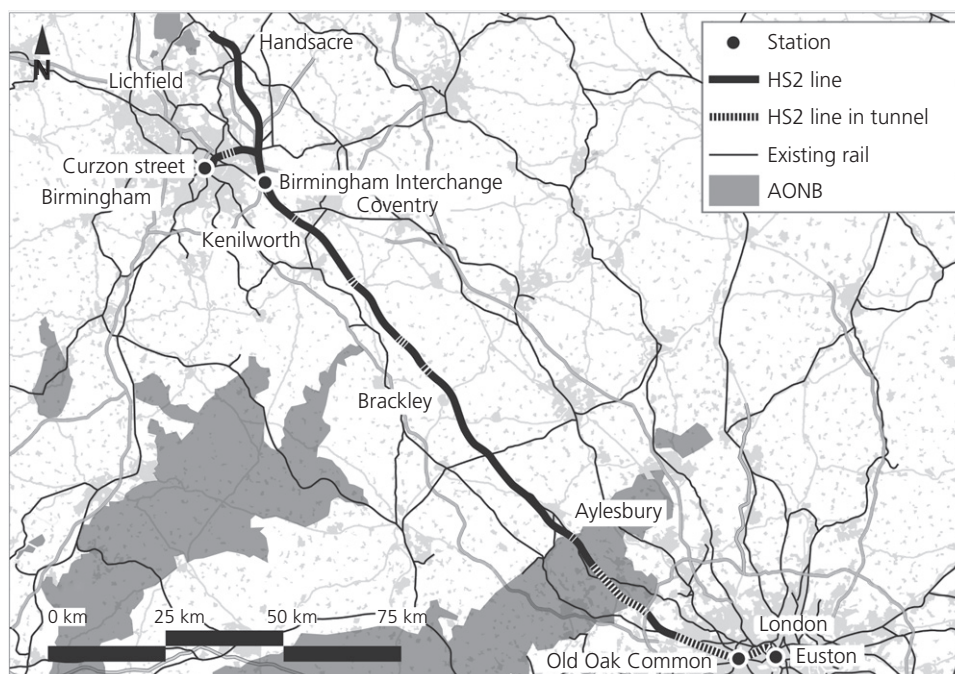


Figure 1. HS2 phase 1 route. AONB, area of outstanding natural beauty

- overall, there is a commitment to achieve an ‘excellent’ Building Research Establishment environmental assessment method (Breeam) sustainability rating.

Phase 1 is planned for completion in 2026. Legislation to extend the route to Crewe by 2027 (phase 2a) is currently in parliament, and legislation to complete the route to Leeds and Manchester by 2033 (phase 2b) will be deposited in 2019. Eight stations on the high-speed line will be built or redeveloped. HS2 classic compatible rolling stock will run at high speed along the new HS2 line and then switch over to conventional tracks at Handsacre when phase 1 opens, Crewe when phase 2a opens, and at Manchester and Leeds following completion of phase 2b. On phase 1, new stations will be built as HS2 trains will continue on up the East and West Coast main lines, serving towns and cities in the north of England and Scotland. This will provide millions of people with access to the new high-speed network.

3. Stages in the development of HS2 phase 1

The evolution of these proposals has been articulated into distinct stages, each ending with revised scheme proposals as given below.

- March 2010 initial ‘preferred route’ – HS2 Ltd produced its initial report to government *High Speed Rail: London to the West Midlands and Beyond* in December 2009 (HS2, 2009). This report recommended a preferred route from Euston to Birmingham and to a junction with the

West Coast main line just north of Lichfield broadly on the same alignment as the current proposal. In March 2010 the then secretary of state, Andrew Adonis, published the ‘initial preferred route’ and presented his response to the HS2 Ltd proposals to parliament in a document entitled *High Speed Rail* (DfT, 2010) generally endorsing the proposal for a ‘Y’ shaped route to Leeds and Manchester, while making it clear that no firm decisions would be taken until after the public had been consulted.

- February 2011 ‘Consultation route’ – further work during 2010 led to a number of detailed changes to the preferred route, mainly to reduce adverse effects on neighbouring communities and the environment. The amended scheme, which included proposals for serving Heathrow left unresolved in March 2010, formed the basis of the formal public consultation between February and July 2011.
- January 2012 ‘post-consultation route’ – having considered all the responses, the secretary of state, Justine Greening, published the post-consultation route together with supporting documentation. The amendments following consultation included alignment changes and additional and extended tunnels.
- Public consultation May–July 2013 – work continued during 2012 to refine the proposals and assess the effects. There was continuing engagement with communities and stakeholders and a further round of public consultation from May to July 2013 on significant route refinements and on a draft of the environmental statement (ES), which included the mitigation proposals.

- November 2013 bill deposit – the bill scheme incorporated detailed mitigations and the refinements consulted on earlier in the year. The bill included plans and sections showing the land over which powers were sought and was accompanied, among other things, by an ES showing details of the scheme, mitigations and construction arrangements.
- 2014–2016 amendments in parliament – amendments during the House of Commons select committee stage (House of Commons, 2016) were made through five additional provisions to the bill, each of which was accompanied by a supplementary ES. During the parliamentary stage numerous undertakings and assurances were given that often changed detailed aspects of the scheme to reduce local adverse effects.
- February 2017 royal assent for the HS2 Act.

3.1 Community involvement

Before the announcement of the initial ‘preferred route’ in 2010, consultation was limited mainly to discussions with some local authorities, transport agencies and others on a confidential basis in order to minimise the extent of public uncertainty and blight. After March 2010 the options could be discussed more widely with interest groups and affected parties so as to develop the proposals and advise stakeholders prior to formal consultation.

The general public and a much wider range of organisations have been engaged since the start of the formal public consultation in 2011. This was particularly so following the setting up of 26 community forums (one for each route section) in March 2012. Throughout the development of the HS2 design, consultees made proposals and suggestions for different routes and options. Each was considered.

As the proposals became more detailed, engagement with public authorities, community groups, affected landowners and adjacent occupiers increased with the aim of reducing impacts and resolving local problems. This process led to numerous changes to the scheme proposals as well as numerous undertakings and assurances.

4. Option generation and selection process

From the outset, the Department for Transport (DfT) and HS2 Ltd applied government business case methodology for preparing and assessing proposals. There are three reasons why a consistent, comprehensive and structured approach to option generation, analysis and selection is essential in developing major infrastructure proposals.

- To ensure regulatory compliance. Consideration and selection of options is a government economic requirement in order to obtain best value for money from public investment. It is a central feature of Treasury guidance on business case appraisal and evaluation

(HM Treasury, 2015: p. 12): ‘The key to a well scoped and planned scheme is the identification of the right range of options, or choices, in the first instance; because if the wrong options are appraised, the scheme will be sub-optimal from the outset.’ *The Green Book* guidance (HM Treasury, 2015) also specifies consideration of a ‘do nothing’ option against which to appraise the ‘do-something’ options.

There is a statutory requirement for optioneering in environmental regulations but it is not as comprehensive or prescriptive as in *The Green Book* (HM Treasury, 2013). The Environmental Impact Assessment Regulations (HMG, 2011) – which apply to hybrid bills under Parliamentary Standing Order 27A (House of Commons, 2017) – require the hybrid bill to be accompanied by an ES which must include ‘An outline of the main alternatives studied by the applicant or appellant and an indication of the main reasons for his choice, taking into account the environmental effects’ (HMG, 2011: p. 56). For those projects requiring a strategic environmental assessment (SEA), an environmental report must be prepared covering, among other things, ‘reasonable alternatives, taking into account the objectives and the geographical scope of the plan or programme’ (EC, 2001: para. 14). However, in 2013 the Supreme Court determined that the SEA directive did not apply to the HS2 proposals.

- To generate the best scheme possible. Developing and appraising options can be time consuming, so a mechanism is needed to ensure that defective or sub-optimal options are discarded as soon as a ‘show stopper’ is identified or where one option is inferior to another in every significant respect. Resources can then be directed towards development and analysis of the remaining options. HS2 Ltd applied a three-stage process comprising longlisting, shortlisting and selection of the preferred option. In this way it was possible to direct project resources on to the most promising options. This was particularly important during the later stages when detailed design, costing, environmental impact assessment (EIA) and consultation was often necessary in order to explain the reasoning and make informed choices.
- To justify the proposals. Any major project must have a sufficiently robust justification to withstand the challenges of objectors during the approval process. On major projects the case must be made in the court of public opinion as well as through the statutory processes. Clear and documented reasoning for the decisions and choices between options is crucial to justifying the proposals. This has been a vital issue for HS2, which is a controversial scheme, particularly for those along the route who are most affected. Numerous alternative proposals were presented over the last 8 years, ranging from other ways to spend the money and radically different routes to minor local mitigations. By the time the bill was deposited almost all the alternatives proposed by objectors had been

considered by the promoter at the appropriate time in the development of the project, although objectors have not necessarily agreed with the choices made.

As the option-selection process progressed, the range of different alternatives narrowed and the level of detail and consultation increased (see Figure 2). Both the proposals and the evaluation were developed and refined for public consultation in 2011, when a suite of accompanying engineering, economic and environmental documents was published with the consultation document.

After January 2012 it was possible and necessary to have a more detailed approach to comparison of local options and mitigations. Figure 3 illustrates the activities surrounding the

sifting process at this stage. The appraisals were summarised in sift tables with the various factors grouped under 11 headings. For the more specific choices of options, the relevant aspects of the scheme were prepared in sufficient detail for cost estimates on a like-for-like basis built up from elemental cost components, and for an environmental analysis covering all the EIA topic areas.

Where major changes to the alignment were proposed, the public were consulted before a decision was made. In cases where new information on issues such as engineering feasibility, environmental effects, cost or stakeholder representations called into question a previous choice of alignment or infrastructure option, a review was instigated to revisit the original decision and if necessary choose either a new option or one that had been discarded at an earlier stage. In most cases decisions were taken on a balanced view of a range of factors and only rarely were they governed by a single consideration.

5. Strategic high-speed route options

Although HS2 phase 1 is a discrete project that can be justified on its own merits, from the outset it was conceived as the first element of a long-term network of high-speed lines to improve connections between the major conurbations, and specifically the four largest – London, Birmingham, Manchester and Leeds. The first task was therefore to consider how a route from London to the West Midlands might be subsequently extended to the north so that the first phase could be planned in the context of the best strategic option for subsequent extension.

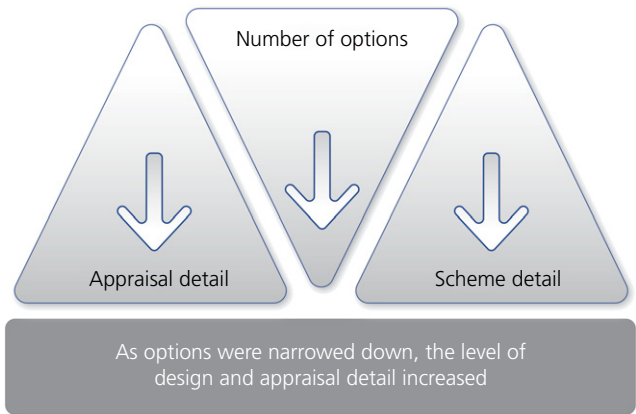


Figure 2. Option refinement process

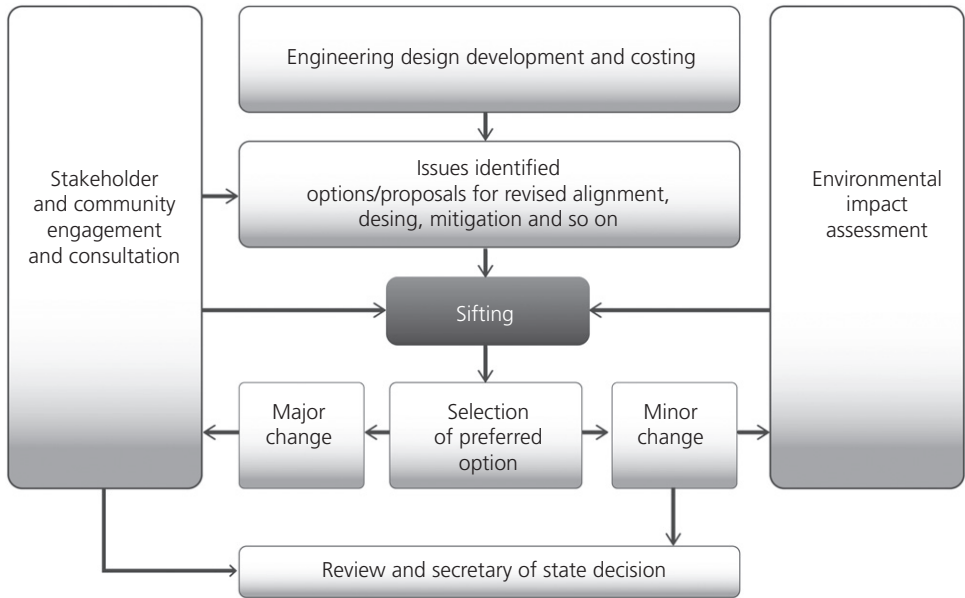


Figure 3. Scheme refinement 'sift' process

The strategic choices are determined by the locations of the major cities, which suggested a network based on a western route to Liverpool/Manchester, and an eastern route by way of some or most of the cities in the East Midlands, and South and West Yorkshire. North of Leeds, Teesside and Tyneside lie on the eastern route, but there are no conurbations in the North-west to the north of Manchester. In Scotland, there are a number of permutations for serving Edinburgh and Glasgow, but in order to create a like-for-like comparison of the routes through England, all options considered by HS2 Ltd assumed the same configuration in Scotland. With this geographic context in mind, three families of options were prepared in outline, then analysed and compared (see Figure 4).

Although there are numerous environmental features and issues that could influence detailed route choice, no environmental or sustainability issues were identified that would affect the strategic decision on whether HS2 should be extended on both sides of the Pennines or only on the east or west side. The 2010 demand and business case analysis of the proposals concluded that the inverse 'A' had a significantly better benefit–cost ratio (BCR) than the reverse 'E' or the reverse 'S', respectively, reflecting the following characteristics of the options.

- Inverse 'A' would be the most expensive because the total length of the route is so much greater, but it would provide much better value for money because it connects London and Birmingham directly to both sides of northern England. It would be more comprehensive, would offer better overall journey times, particularly to Scotland, and the benefits would be consequently much greater.
- Reverse 'E' could not offer better journey times from London or Birmingham to Manchester/Liverpool than

HS2 trains continuing to the North-west from Lichfield by way of the West Coast main line.

- Reverse 'S' would be the least expensive of the three families of options, but offered the lowest value for money because it could not serve the East Midlands or Sheffield and the time savings to Leeds, the North-east and Scotland would be much less than the other two options.

After considering the consultation responses, in January 2012 the government confirmed its intention to promote hybrid bills for the 'Y' network (i.e. the inverse 'A' but no further north than Manchester and Leeds and without the trans-Pennine link between these cities). In 2016 the government provided funding to progress proposals for the route between Manchester and Leeds ('HS3') which, if implemented, would complete the inverse 'A'.

6. Route and station options considered

The process for selecting HS2 Ltd's recommended route in 2009 began by dividing the scheme into components. Options for each of these were sifted using a number of criteria, including 'strategic fit', cost and engineering feasibility, demand and environmental impacts. The proposed route was identified through a staged process of narrowing down options from a longlist to a single recommended option and, where necessary, alternatives depending on the choices of other elements. The elements were then fitted together to produce an initial proposal.

6.1 London and Birmingham station options

Figure 5 shows the three-stage process for considering and selecting location options for the London and Birmingham termini considered in 2009. A longlist of 27 London and

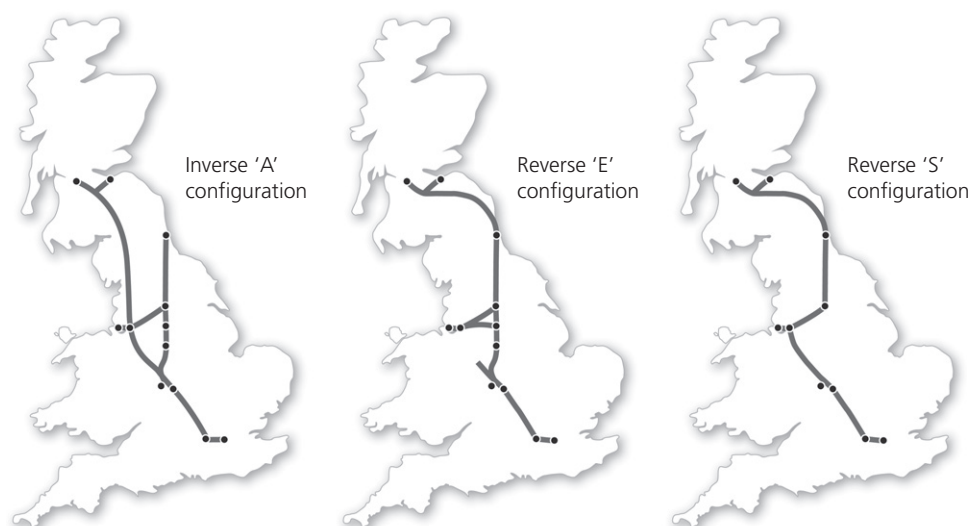
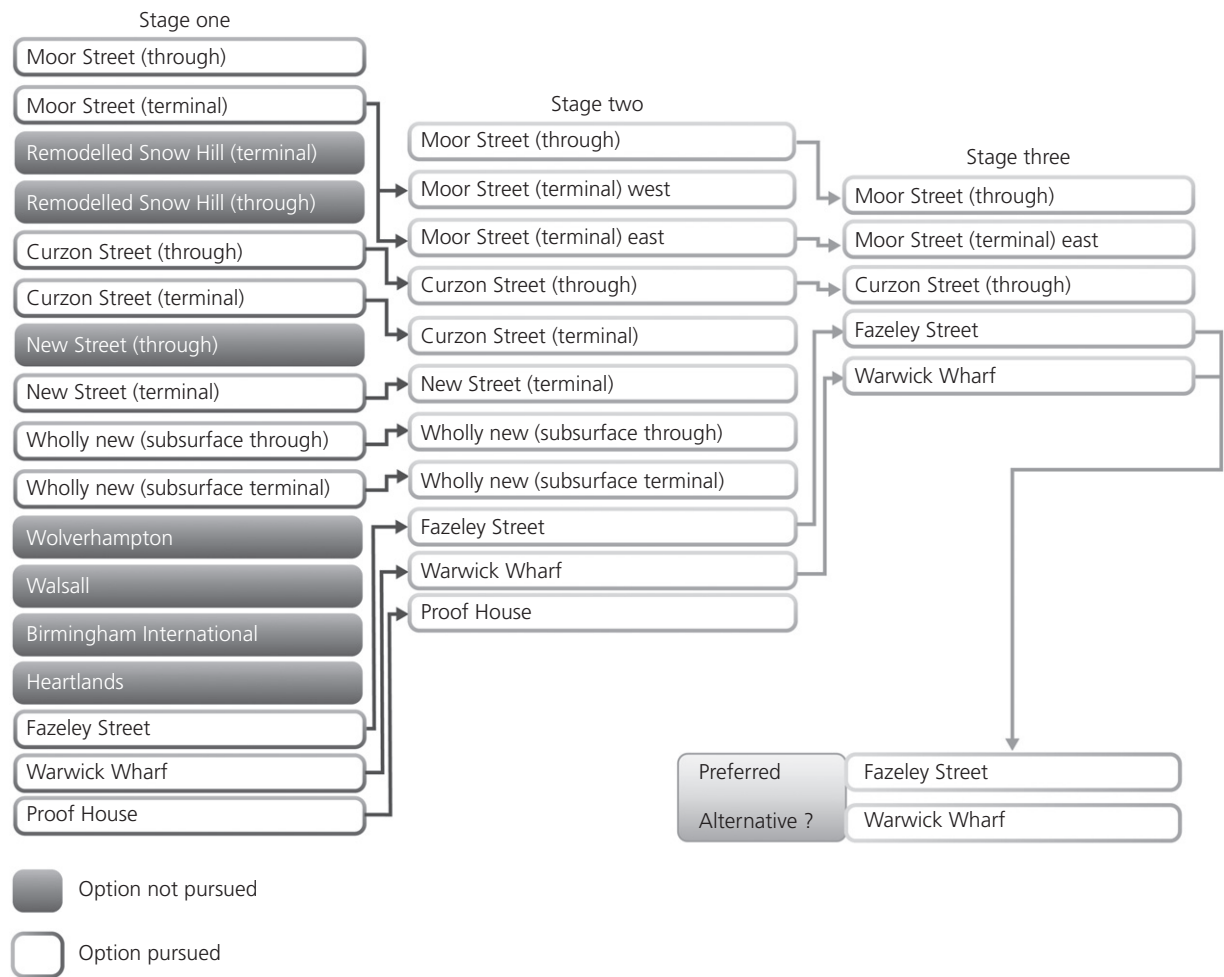


Figure 4. Strategic route options



(a)

Figure 5. (a) Birmingham and (b) London station options (continued on next page)

13 Birmingham station locations was considered at stage one. These were analysed at a very high level on the basis of engineering and operational feasibility, the relative likely demand and an indication of the relative costs (i.e. high, medium, low). Planning and environmental considerations were also addressed at a very high level at this initial stage. Those station options that had obvious significant operational difficulties were identified. In this way the options were whittled down to a shortlist of the more promising station locations, in parallel with a similar process on the routes.

For the stations identified in the shortlist (stage two), each was considered in terms of how well it met the remit from government, demand, its relative cost, its construction and operational feasibility and its environmental impacts. This included a review of how passengers would travel to and from HS2 stations covering road, rail and local public transport (including London Underground) links. The assessment also took into account environmental, social and spatial planning

considerations, passenger demand and any relevant considerations of likely relative passenger numbers and journey times. From this analysis a clear preference emerged for both London and Birmingham.

6.2 Options for the route between London and the West Midlands

A similar process was adopted for choosing a route between London and the West Midlands (see Figure 6). In addition to seeking to avoid towns and villages along the lines of the route, HS2 Ltd considered environmental and wider impacts of route options as part of the appraisal of sustainability, which was an integral element of the sifting process. This looked initially at only high-level priority factors such as nationally and internationally designated sites and areas, including special protection areas and AONBs. At stage three the options were developed in more detail and assessed using high-level comparisons to identify a single route and station proposal in each case. The most direct route (route 3) emerged as

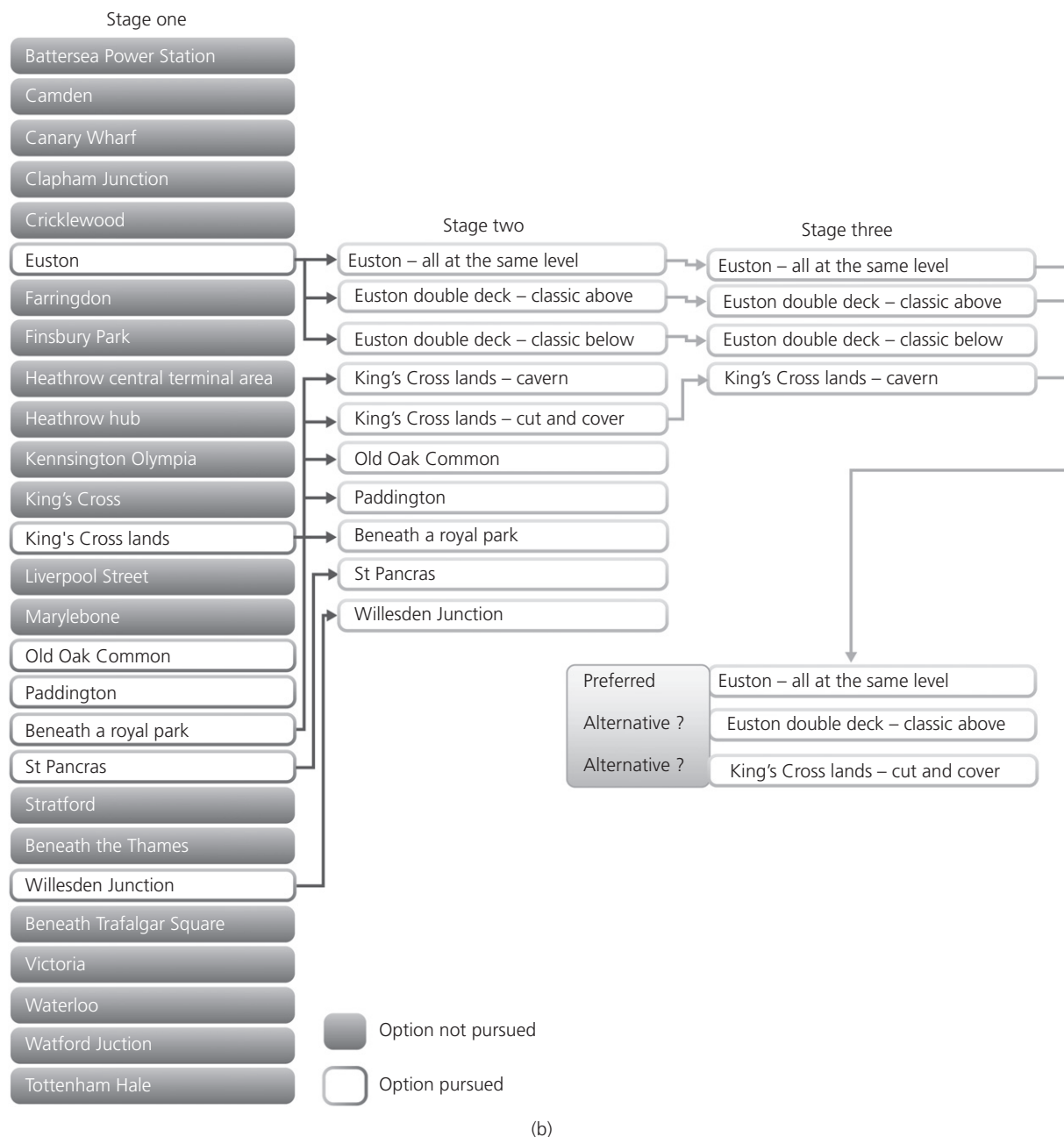


Figure 5. Continued

preferable to a route broadly following the West Coast main line north to Leighton Buzzard (route 4).

Probably the most controversial section was the route across the Colne Valley and through the Chilterns AONB (see Figure 7). Tunnel alternatives to the Colne Valley viaduct were considered and debated at length in parliament. However, both select committees concluded in favour of the viaduct option accompanied by a wide-ranging and extensive package of mitigation measures and funding for compensatory enhancements.

Although HS2 does not traverse the narrowest part of the Chilterns AONB, of the 21 km route through the AONB, 63% will be in tunnel and 27% in cutting. As with the Colne Valley, the scheme includes comprehensive measures to mitigate the environmental effects.

6.3 Interchange and intermediate stations

Intermediate stations were also considered in this process. For the interchange, ten possible locations were considered, as well as having a terminus and no intermediate station (see Figure 8).

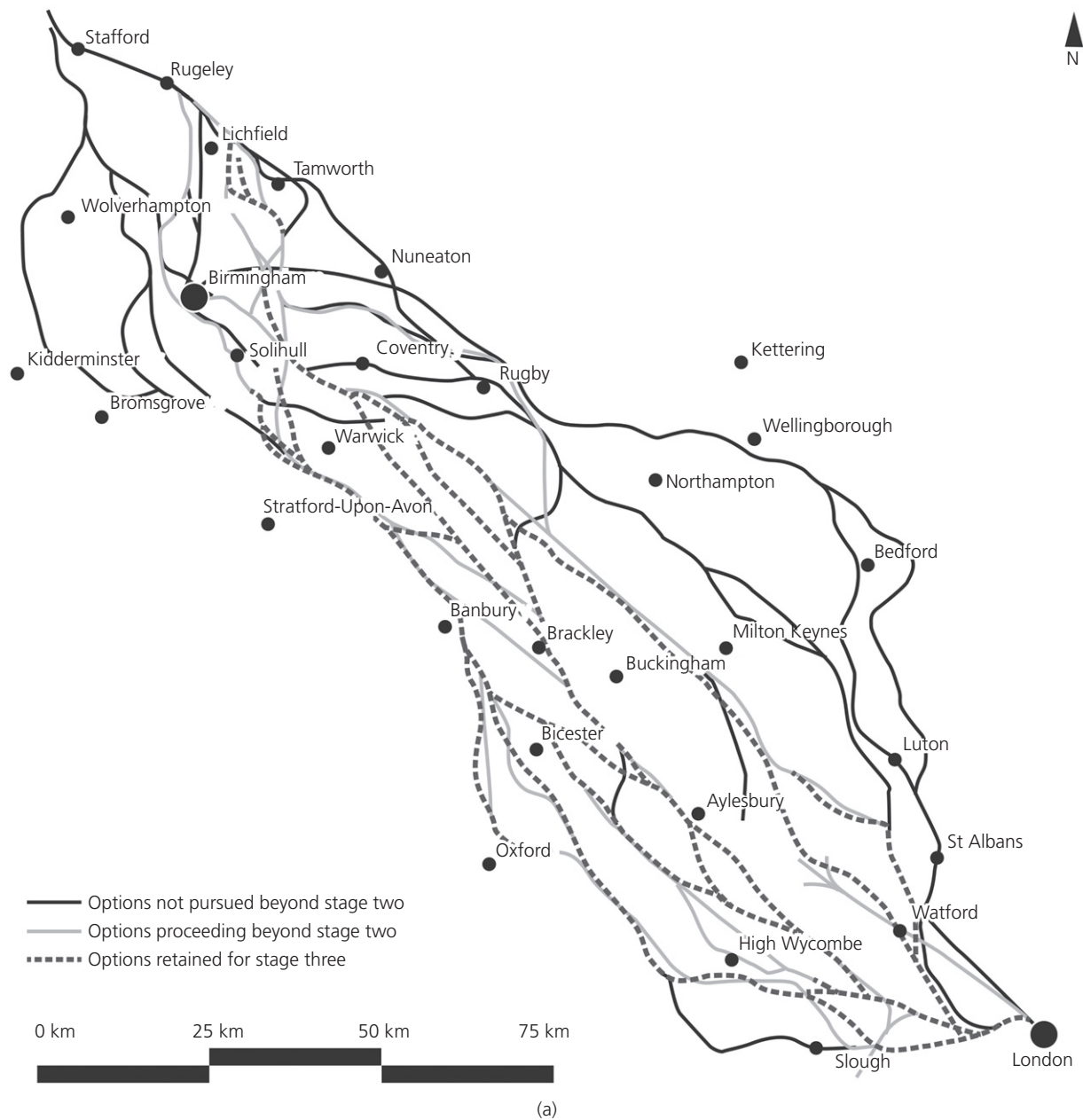


Figure 6. (a) Route options. (b) Route shortlist (continued on next page)

For various reasons, those on the west were not viable. Heartlands was too close to the terminus to broaden the travel market significantly. Those on the east depended partly on which rail corridor was chosen for the route into Birmingham (which also affected the terminus location). Having analysed the options, a site east of Birmingham international airport and the National Exhibition Centre was selected.

Twelve intermediate station locations between Aylesbury and Coventry were also considered and reduced to a shortlist of

three – Aylesbury, Bicester and Milton Keynes. All three were rejected partly because they would have a very poor business case and partly because any intermediate station south of Birmingham Interchange would have significantly reduced the overall capacity of the route.

6.4 London interchange and Heathrow connections

In 2009/2010 the government was keen to exploit opportunities for improving international connections in line with the recommendations of the Eddington report (Figure 9). In the



Figure 6. Continued

West Midlands, phase 1 would connect to Birmingham international airport, but in London there was an aspiration in the project's remit to connect both to Heathrow and to HS1. These were recurrent issues that were not finally determined until after the House of Commons select committee stage of the bill (see Section 7 below).

Access to Heathrow and the Great Western main line were considered together. In 2009/2010 eleven locations were analysed, including three at Heathrow airport and most of the existing Great Western main line stations between Old Oak Common and Iver. At the same time, alternative routes included serving

Heathrow either directly on the main route from London to the West Midlands or by way of a loop or a spur. The issue was left unresolved in March 2010, and so Lord Mawhinney was asked to review the options and more work was commissioned in the summer of 2010, including additional locations not previously considered.

In 2011 and 2012 the government concluded that Old Oak Common would be the best location because, for the vast majority of passengers, it offers a second route into central London on the Elizabeth line. Also it would already be connected to all four Heathrow terminals (by way of the Elizabeth

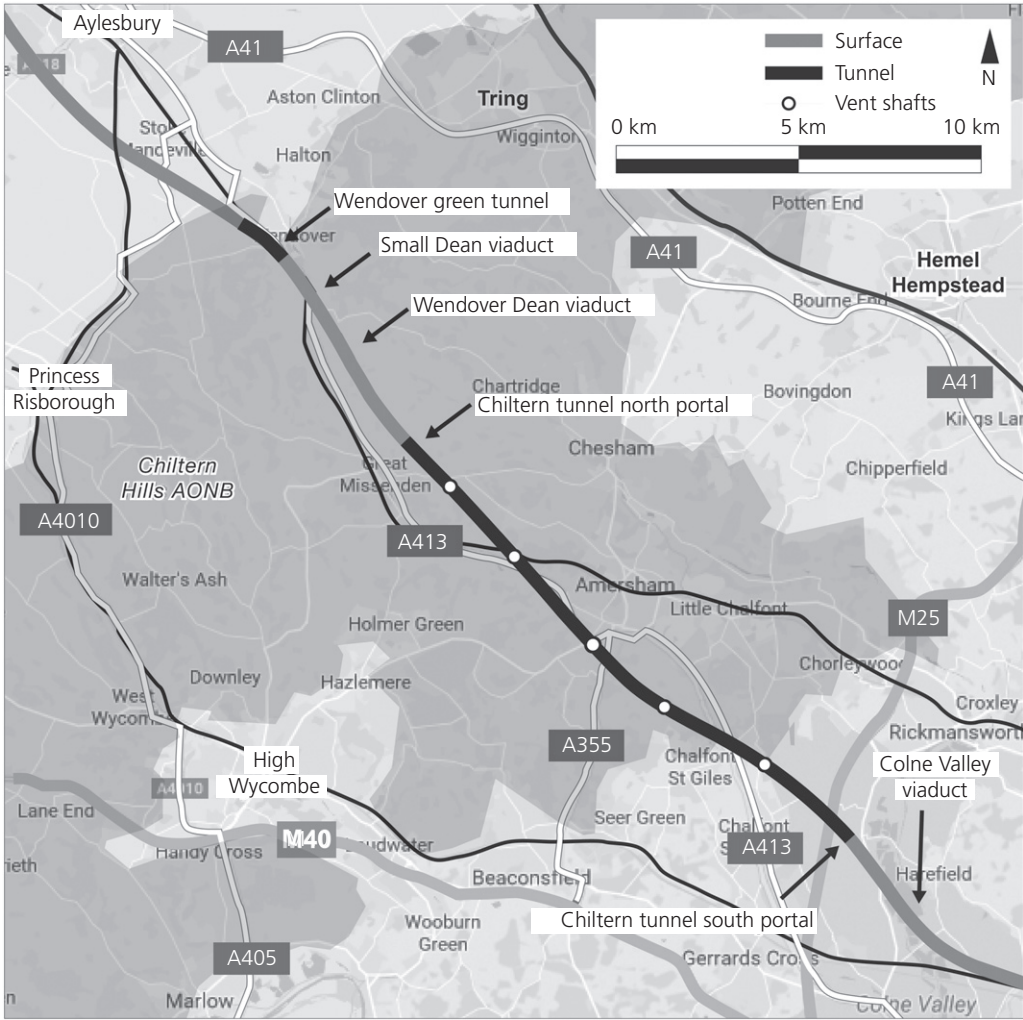


Figure 7. Route through the Chilterns AONB

line and Heathrow Express) and would have major potential for regeneration. Irrespective of route options, proposals to run direct trains to Heathrow did not have a strong economic case, as less than 10% of HS2 passengers are travelling to the airport, and there would be a significant delay to all the other passengers on these trains.

6.5 Connection to HS1

From an early stage in the evolution of the proposals, the government supported the strategic case for a direct rail link from the midlands and the north to the continent. However, likely passenger demand is limited and providing a physical link would have presented formidable engineering, operational and environmental problems. Various tunnel/surface route options connecting Old Oak Common to HS1 were considered between 2009 and 2011, and despite the high cost a route by way of the North London line was included in the hybrid bill in November 2013.

The proposal would have entailed problems on the North London line, including operational issues and environmental effects through the residential area during construction. Following a review by Sir David Higgins, in March 2014 the government decided to remove it from the bill. Indirect links from HS2 to HS1, including a ‘people mover’, were also considered both at an early stage and subsequent to the decision to abandon the rail link. However, none was viable as Euston and St Pancras are only 500 m apart and already connected by underground lines and buses.

7. Chronological evolution of the HS2 phase 1 scheme

7.1 The ‘initial preferred route’ and the ‘consultation route’

In March 2010 the secretary of state generally concurred with HS2 Ltd’s recommendations subject to further work

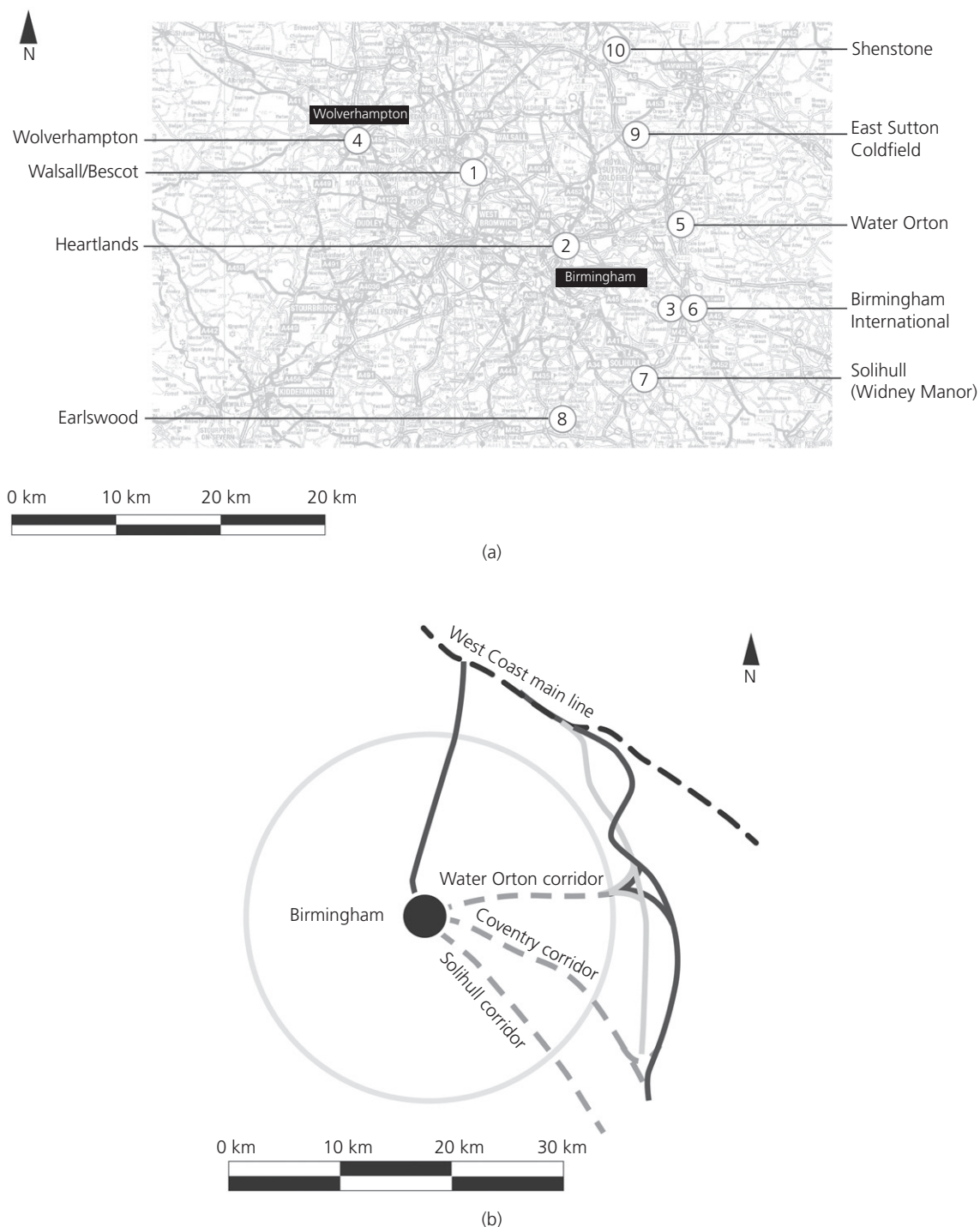
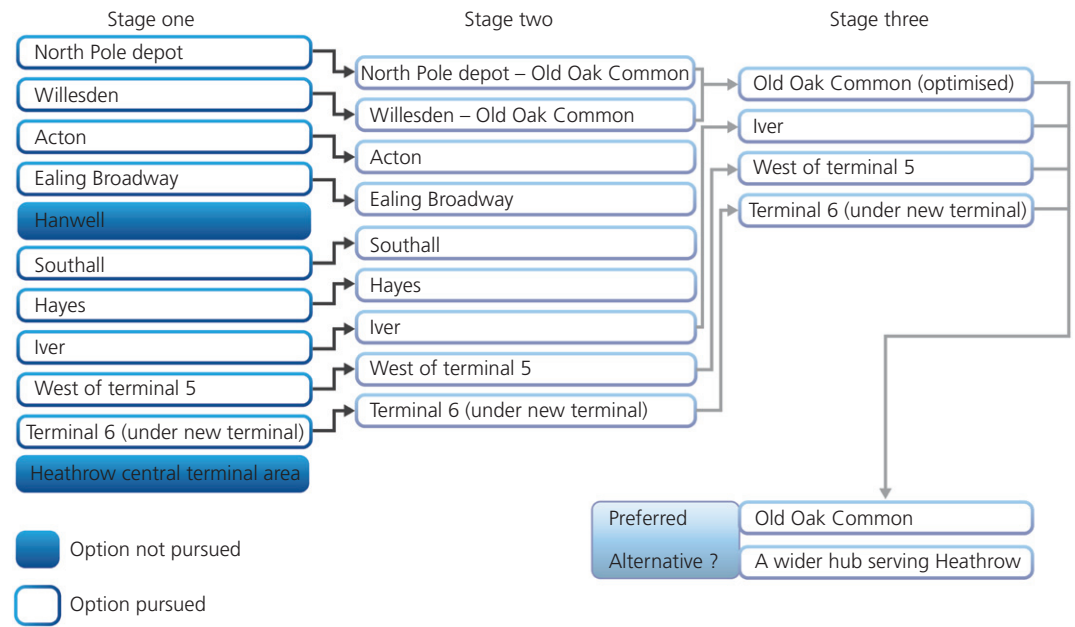


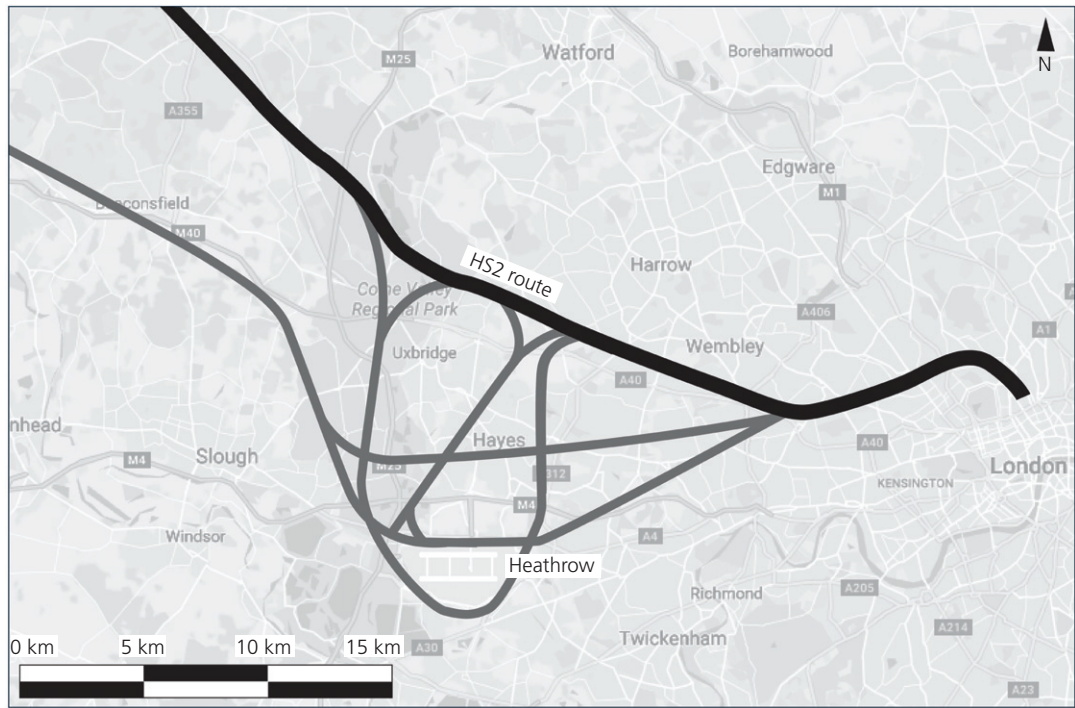
Figure 8. (a) Routes into Birmingham and Birmingham interchange station options. (b) Smaller Birmingham map

on mitigation but, as already described, deferred consideration of options to serve Heathrow. The 'consultation route' in February 2011 was a comprehensive proposal including depots and specific proposals for links to Heathrow and HS1. The main changes in the route were alterations to alignments to reduce environmental impacts – approximately

half the length of the route had been altered in some way by this stage. The length in tunnel was increased with additional green tunnels in the Chilterns, Chipping Warden and Burton Green and there were numerous alignment changes generally to take the route further away from towns and villages.



(a)



(b)

Figure 9. (a) London interchange and Heathrow options. (b) Heathrow map

7.2 The ‘post-consultation route’

Following the national public consultation the government considered the 55 000 responses received and commissioned some further work. Then in January 2012 it published the ‘post-consultation route’ and *High Speed Rail: Investing in Britain’s Future – Decisions and Next Steps* (DfT, 2012),

together with over 30 supporting documents. Among other things, the decisions document

- rejected the ‘do nothing’ option, a new conventional-speed line or upgrades
- confirmed the ‘Y’ network to be implemented in two phases

- determined the broad route alignment and stations at Euston, Old Oak Common, Birmingham Interchange and Curzon Street as the scheme for which the government would seek parliamentary powers
- incorporated numerous changes to the vertical and horizontal alignment into the proposed scheme, mainly to reduce the impact on towns and villages along the route; additional green tunnels were proposed at Turweston and Greatworth and the alignment of the Chiltern tunnel was moved to the north to avoid an important aquifer
- confirmed the government's intention to consider a spur to Heathrow as part of the phase 2 proposals to Leeds and Manchester.

7.3 The original bill scheme – January 2012 to November 2013

Having selected the broad route alignment and the station locations in January 2012, it was possible to focus the design, construction planning and assessment work as well as most of the public discussion on more local issues and effects. The scheme and construction proposals were developed to 'concept design' stage, sufficient to determine the powers needed to build it and for the proposals to undergo a full EIA.

The scale of the task was immense. The government set up a dedicated group within DfT under its own director general and there was a step change in both HS2 Ltd staff and consultants working on various aspects of the project. Not only was the design developed in much more detail, but there was a greater interaction with the emerging work on assessing the impacts. Mitigations were developed and added to the proposals as effects were identified. During this time the changes and additions were discussed informally with the affected stakeholders and at community forum meetings.

As a result of this work a draft of the ES was prepared that included the mitigation proposals, and further refinements to the scheme were proposed including two additional tunnels (from Old Oak Common to Northolt and from Castle Bromwich to Bromford, which were included when the environmental and cost implications of a surface route became apparent) and revised scheme for Euston. There was a formal public consultation on both from May to July 2013. The secretary of state announced his decisions on the refinements shortly before the bill was deposited and the changes to the mitigation proposals were incorporated into the main environmental statement deposited with the bill.

7.4 Changes made during the House of Commons select committee stage

A large number of changes were made during the House of Commons select committee stage through the deposit of five additional provisions, each accompanied by a supplementary environmental statement. The most numerous changes were additional powers over land for utility diversions following

discussions with the utility undertakers, but there were also many amendments following negotiations with petitioners and at the behest of the select committee. The biggest changes were a new scheme for Euston station and replacement of 6 km of embankment east of Lichfield with a cutting. There was also an additional 1.7 km of tunnel in the Chilterns, making a total of over 48 km of the route in tunnel.

During the parliamentary stages of the bill the environmental safeguards were strengthened by over 2800 undertakings and assurances covering both route-wide policies and standards and specific local issues.

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