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Interface management on high speed two: managing multiple complex interfaces in the design and construction of high speed railway infrastructure in the United Kingdom

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Abstract

Purpose – Interface management is the process of managing communications, responsibilities and coordination of project parties, phases or physical entities which are dependent on one another. Interface management is a crucial part of managing any construction project – but particularly important for high-speed railway projects that often have several contractual parties and stakeholders, very long project timelines and huge upfront cost overlays. This paper discusses how various project interfaces were managed during the design and construction of the civil engineering infrastructure for the High Speed Two (HS2) project in the United Kingdom.

Design/methodology/approach – The paper uses the case study methodology. Key interfaces on the HS2 project are grouped into various categories and the paper discusses how they were managed within the Area North Integrated Project Team (IPT) of the HS2 project made up of contractor Balfour Beatty VINCI (BBV), the Mott MacDonald SYSTRA Design Joint Venture (DJV) and client HS2 Ltd. 3 different case studies drawn from across the IPT are used, each of them highlighting different interfaces and how these interfaces were managed.

Findings – The paper shows how innovative technical designs and modern methods of construction were used to address some of the unique and peculiar challenges of designing a brand-new railway in the United Kingdom. Addressing the contrasting and often competing requirements of different stakeholders, coupled with challenging physical constraints of the very limited land available for the project and the use of a rarely used Act of Parliament in the delivery of the project required different approach to interface management. Collaboration and proactive stakeholder engagement are necessary for successful interface management on megaprojects. The authors posit that adopting an integrated approach to engineering and construction management is an essential ingredient for the successful delivery of high-speed railway projects.

Originality/value – With many high-speed railway projects around the world coming up in the next few years, understanding the context and challenges for each country will help engineering and design managers adopt appropriate approaches for their projects. The lessons learned on the HS2 project are also transferable to other mega infrastructure projects with complex project interfaces.

Keywords Interface management, Design management, Design constraints, Project management

Paper type Case report

1. Introduction

High Speed Two (HS2) is the new high-speed railway for the United Kingdom. It runs between the two largest cities, London and Birmingham, with trains continuing further to the north of England and to Scotland using the conventional railway network. By improving the railway connectivity between these two cities, HS2 will create a corridor of economic opportunity and

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promote social mobility between them and around the country (HS2 Ltd, 2025). HS2 is also more than just a high-speed railway line. At peak construction HS2 will employ more than 30,000 people and support more than 4,000 local businesses thus creating a skill base in engineering, construction and business that will last a lifetime.

1.1 Literature review

This paper focuses on interface management in the design and construction of the HS2 project. Within the context of construction projects, an interface occurs at the boundary between independent but interacting systems, organisations, stakeholders, projects phases/scope or construction elements (Chen, Reichard, & Beliveau, 2007). Interface management is the process of managing communications, responsibilities and coordination of project parties, phases or physical entities which are interdependent (Nooteboom, 2004). In the construction industry there is a growing realisation that good project management is tied to good interface management. Weshah, El Ghandour, Jergeas, and Falls (2013) carried out a web-based survey which confirmed that interface management is one of the major keys for construction project success and that projects with poor interface management capabilities also have poor overall project performance.

Construction projects are now becoming larger and more complex to execute, particularly due to the advances in technology which enhances the ability to have many project parties and stakeholders working together across different geographical locations. Therefore, a robust process of not only identifying interfaces, but monitoring and managing them throughout the project lifecycle is required (Shokri *et al.*, 2012).

There exists a rich repository of literature reviews on interface management in mega construction projects. For example, a research based on experiences in the oil and gas industry found that an integrated approach to managing projects created better cross-discipline relationships which helped to provide teams with better information for decision making and thus helped to improve project performance, (Shokri & Maloney, 2015). A separate study on offshore oil and gas projects found that the use of interface management to all project elements helped to achieve and even improve project goals in terms of safety, quality, schedule and budget (Poddar & Sue, 2016). Other studies have looked at the role of interface management as a tool to enhance the effectiveness of managing construction projects (Keerthanaa & Shanmugapriya, 2017). A recent study took an empirical evidence approach to explore the relationship interface management and project success on a sample of construction projects (Ju, Zheng, Liu, & Shen, 2025). The results of the study showed that interface management positively affects project success in complex capital projects, and this effect was achieved by fostering positive relationships among project stakeholders. Another study showed that trust, openness and effective communication are essential in improving interface management on international engineering procurement and construction (EPC) projects (Shen, Tang, Wang, Duffield, & Hui, 2017).

This paper aims to supplement the existing literature with a focus on a specific type of complex construction project, high speed rail. There is a limited body of research focusing on how high speed railway projects are delivered - the little that exists seems to focus on why high speed rail projects are required, or why they fail. The number of high speed railway projects has grown rapidly in the last few decades. In 1995 there were just under 5,000 km of operational high speed rail tracks in the world, but this has grown almost tenfold to nearly 50,000 km by 2025 (International Union of Railways (UIC, 2025)). By their linear nature, high speed rail projects tend to be very large and complex. They are also often funded by governments or the public sector due to their strategic importance. High speed rail projects have very long timespans, from initial planning and project approval through to design, construction and commissioning. The number of stakeholders on high speed rail projects tends to be very large, from contractors, designers, national government departments and agencies, local planning authorities, statutory approval bodies and others.

Major construction projects, including high speed rail projects, are often plagued by programme delays and cost overruns. A study on a Portuguese high speed rail project found that variability in the construction process, correlation between various repeated activities and disruptive events were the three major drivers of delays and overruns (Moret & Einstein, 2016). Another study from the Swedish high speed rail project found that mega projects tend to run late, overrun their initial cost estimates and often fail to deliver the expected benefits (Ronnie, 2019). These studies show the need to reduce delays and manage costs and that effective interface management is one way in which Project Managers can achieve this within the internal project setup. A separate study focusing on construction accidents on high speed rail projects in China found that interface management with key stakeholders like clients, designers and construction supervisors helped to reduce accidents on projects of high complexity (Han, Shen, Zhu, An, & Bao, 2024). Therefore, there is evidence from the literature that interface management helps projects to achieve their objectives by engaging stakeholders early in the design and construction process. The present study builds on this theme by focusing on experience from one high speed railway project.

2. Methodology and study context

2.1 Case study methodology

The paper discusses interface management using the authors' experiences from the HS2 project in the United Kingdom. A case study is a study about a person, a group of people or a unit which is aimed to generalise over several units (Gustafsson, 2017). Gustaffson (2017) further argues that the case study method is not aimed at analysing cases but aims to define cases and explore settings and context in order to understand them. For this paper, 3 separate sub-case studies, each focusing on a different type of interface, are used to illustrate how interfaces were managed. By using the case study approach, the authors sought to get an in-depth understanding of how the project was run without intervening to change the outcome. Using real-life examples and analysing a project within its natural setting provides useful learning points which can be used or adapted for future projects. As the authors were also participants on the project, the case study approach gave authors access to multiple sources of data, including documents, technical standards, formal and informal interviews and archives. Although the measure of project success can be subjective, for this paper the achievement of stakeholders' requirements was a specific measurable outcome which could be objectively identified.

Before describing the three case studies in detail, the paper provides a general overview of the HS2 project and interface management on HS2.

2.2 Design and building contracts on HS2

The Design and Build contracts for delivering the civil engineering infrastructure for HS2 were awarded to four large consortia of national and international civil engineering contractors, as shown in Figure 1. These design and build contracts, known as Main Works Civils Contacts (MWCC), are only a part of several contracts that have been awarded to deliver the whole of the HS2 project. Figure 1 shows the route of HS2 and the Main Works Civils Contract.

2.3 Overview of the Area North contract

This paper discusses how project interfaces have been managed in the Area North (N1 & N2) Main Works Civils Contract. This contract was awarded to Balfour Beatty VINCI (BBV), a consortium made of Balfour Beatty Limited and VINCI. BBV in turn appointed a Design Joint Venture (DJV) made of up design consultants Mott MacDonald and SYSTRA. BBV is responsible for the Area North contract which runs from Long Itchington in Warwickshire to Handsacre in Staffordshire including the spur into Birmingham City Centre (Figure 2). BBV's

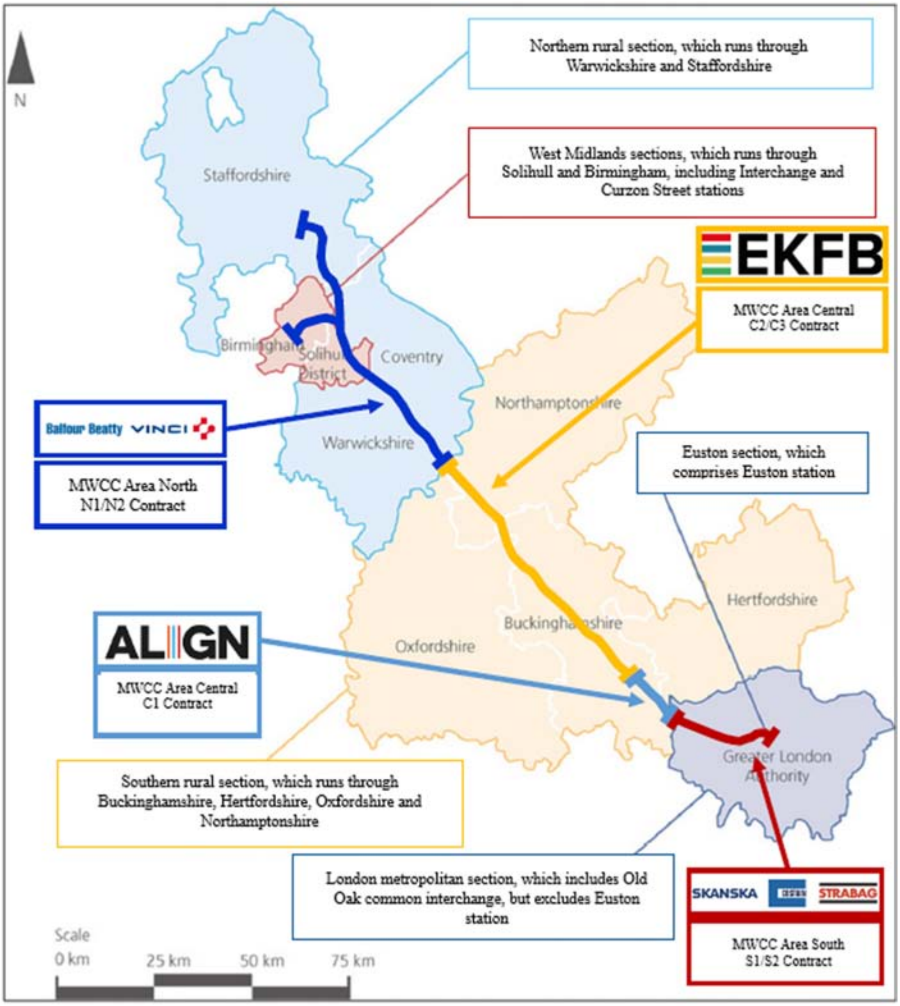

Figure 1. Map of the HS2 route. **Source(s):** Adapted from Blight (2021)

scope of works includes the design and construction of viaducts, bridges, tunnels, culverts, retaining walls and earthworks for a 90 km stretch of HS2 (Figure 3). There are also several major utility and highway diversions required to accommodate HS2. Within the Birmingham conurbation HS2 will cross strategic highways and existing railway tracks at several points.

2.4 Interfaces on the HS2 project

An interface occurs at the boundary between independent but interacting systems, organisations, stakeholders, projects phases/scope or construction elements (Chen *et al.*, 2007). On the HS2 project, an interface occurs at project points where there is any physical, functional, operational or process linkage (or information flow) that crosses a contractual, technical or other boundary. Sometimes interfaces are easy to identify; for example, a physical interface of two separate sections of the project. However, interfaces are often more difficult to define, for example where two or more stakeholders are providing some intangible input on the

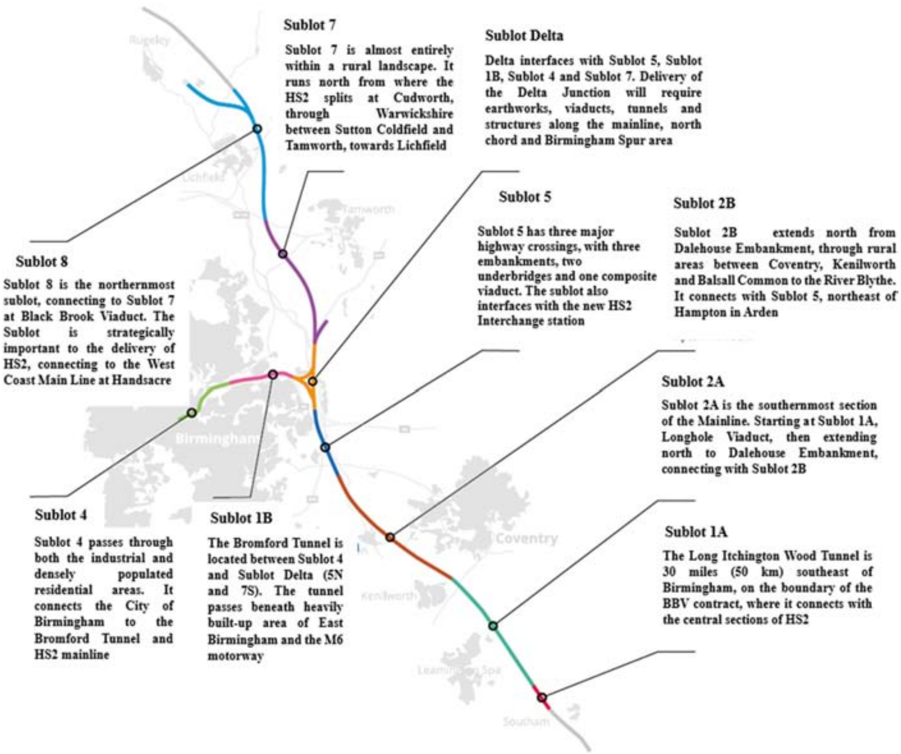

Figure 2. Map of the BBV IPT Area North HS2 route. **Source(s):** Balfour Beatty VINCI (2023)

Figure 3. BBV scope of works in Area North. **Source(s):** Authors' own work

same part of the project, for example by providing consent or approval. Figures 4, 5 and Plate 1 show different types of interfaces on the HS2 project.

There are several stakeholders on the HS2 project, as described later in this paper. The greater the number of contractors, designers, subcontractors, vendors, suppliers and external

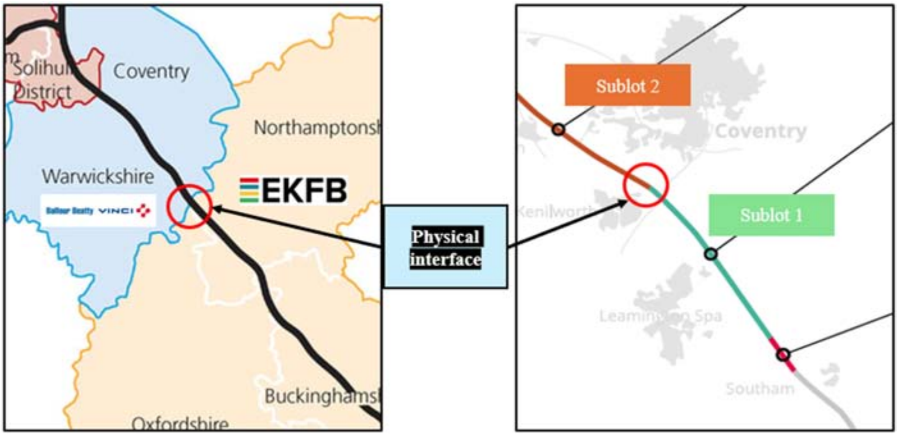

Figure 4. Physical interface – boundary between two contract areas (left) and different sublot teams (right). **Source(s):** Adapted from Blight (2021) (left) and Balfour Beatty VINCI (2023)

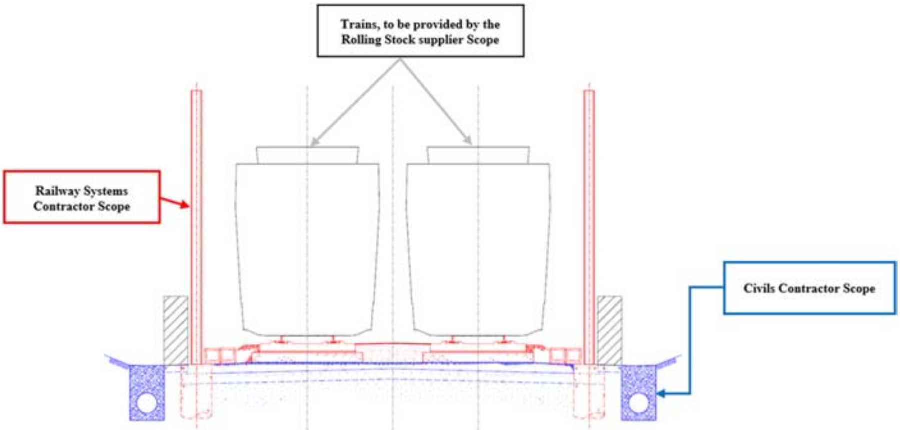

Figure 5. Technical interface between two different contract scopes, blue is scope delivered by the civil works contractor while red is scope delivered by the railway systems contractor. Trains are procured under a different contract. **Source(s):** Authors' own work

and internal stakeholders, the greater the opportunity for miscommunication and conflict. Therefore, interface management is a crucial part of the management of any project, but particularly large construction projects like most high speed rail projects that span several years and can cost several billions of dollars. Missing or incorrectly defined interfaces are often a major cause of cost overruns, engineering variations, claims and system or product failures on projects. Therefore, interface management helps the project by.

(1) Reducing ambiguity on roles and responsibilities of various contracting parties

(2) Identifying potential interface problems early in the project lifecycle and discussing ways to reduce their impact and likelihood

(3) Integrating the interfaces with the programme and ensuring alignment with the scope of works and project objectives

Plate 1. Interface between HS2 and motorways managed by National Highways. **Source(s):** HS2 Ltd (2024a)

For HS2, one by-product of interface management was that it led to innovation and required engineers to think outside the box to address some of the design constraints caused by regulatory requirements and conflicting stakeholder expectations.

2.5 Contractual interfaces

High Speed Two Limited (HS2 Ltd) is a non-departmental public body that has been charged with the responsibility of managing the delivery of the HS2 project. HS2 Ltd is wholly funded by the Secretary of State for Transport and sponsored by the Department for Transport (DfT) in the United Kingdom. It has divided the project into several major contracts that are awarded as the project progresses through the different phases. This is different from other delivery models where contracts are awarded for all aspects of the project right from the start. Table 1 shows some of the major contracts awarded on HS2.

The benefit of having multiple contracts across different phases of the project is to ensure that there is a clear demarcation of responsibilities at each phase of the project. It also ensures that contractors with expertise in certain aspects of the project focus their experience in those areas rather than delivering everything under very few, large, all-encompassing contracts. By having multiple contracts across phases and within each phase the client is also derisking the project in case of poor or non-performance by a contractor. However, with these benefits there are some challenges associated with having several contracts. One major challenge is that having so many contracts on one project increases the complexity of interface management. The matrix of stakeholder engagement becomes very large. Information has to be handed over to different contractors as the project progresses. Design assumptions made by earlier designers may turn out to be incorrect, but it would not be possible to discuss with them as they would have left the project. Without a robust interface management strategy in place the chances of miscommunication, missing scope and misaligned project goals are very high.

2.6 Regulatory interfaces

The works on HS2 are authorised through an Act of Parliament, the High Speed Rail (London to West Midlands) Act 2017 (the HS2 Act). This legislation is enacted through the so-called

Table 1. Various major contracts on HS2, starting from the bottom of the table

Railway Systems Contracts Track systems, overhead catenary systems, operational telecommunications and security systems, third party communications; command, control, signalling and traffic management (CCS&TM), engineering management system, tunnel and lineside mechanical and electrical (M&E) systems, high voltage power supply systems				Several railway systems contracts awarded to provide the track, signalling, communications and other systems required for the operation of HS2 (awarded Q4 2024)
Stations Contracts Euston Station (Q1 2019) Old Oak Common Station (Q3 2019)			*Stations Contract* Birmingham Curzon Street (Q4 2023) Interchange Station (Q3 2022)	Four Main Stations Contracts awarded - two in West Midlands and two in London
Main Works Civils Contract MWCC S1 and S2	*Main Works Civils Contract* MWCC C1	*Main Works Civils Contract* MWCC C2 and C3	*Main Works Civils Contract* MWCC N1 and N2	Four Main Works Civils Contracts awarded - Design and Construct the Civil Infrastructure for HS2 (Awarded Q3 2017)
Enabling Works Contract EWC Area South	*Enabling Works Contract* EWC Area Central		*Enabling Works Contract* EWC Area North	Three Enabling Works Contracts awarded to carry out advance works (site clearance, establishing site compounds, archaeological and ecological surveys, utility diversions, highway realignments. (Awarded Q4 2016)

Source(s): Authors' own work (based on publicly available information)

hybrid bill procedure which incorporates aspects of laws affecting the public with those affecting private individuals (Blight, 2021). Hybrid bills also suspend or limit some aspects of existing legislation in relation to the planning and implementation of construction projects (Podkolinski, 2021). An additional aspect of an Act of Parliament enacted through the hybrid bill process is that it requires the body promoting the project, called the nominated undertaker, to obtain consents and/or approvals of its plans and specifications (drawings and designs) before construction can begin, (Podkolinski, 2021).

The use of hybrid bills is very rare in the United Kingdom. Apart from the HS2 project, hybrid bills have only been used twice before, for the Crossrail project in 2008 (Bennett, 2017) and for the Channel Tunnel project in 1994, (Carling, 1995). Most construction projects are usually authorised through the Town and Country Planning Act 1990 where a development is granted planning permission. Once planning permission is granted no further consents or approvals are required. For larger or nationally significant projects, Development Consent Orders (DCOs) under the Planning Act 2008 can be used, (Rankl, 2024). DCOs do not require additional consents and approvals from stakeholders.

Given that hybrid bill powers are very rarely used and not well known by many people, including many engineers working on the HS2 project, understanding the different regulatory requirements under the HS2 was one of the key interface challenges on the project. Under the HS2 Act some of the existing laws were disapplied while others were modified to suit the specific requirements of the project. Engineers and planning managers on the project had to understand these subtle differences in requirements while still designing the infrastructure. Most of the stakeholders were also not aware of the differences in the requirements, which made the engagement even more difficult. Table 2 shows some of the consents and requirements under the HS2 Act that are usually covered by existing legislation.

Table 2. Various consents required under the HS2 act

Provision in the HS2 act	Description
Schedule 4 Part 1	Consent for providing access to highways
Schedule 4 Part 2	Consent for temporary interference with highways
Schedule 4 Part 3	Consent for construction of new or realigned highways
Schedule 17	Planning Permission Consent
Schedule 24	Carrying out street works (such as utilities diversions) for the purposes of HS2
Schedule 25	Regulation of highway traffic used for the construction of HS2
Schedule 26	Movement of lorries during the construction of HS2
Schedule 27	Management of noise during construction and operation of HS2
Schedule 33 Part 1	Consent for the construction of bridges or structures over or under highways
Schedule 33 Part 5	Consent for discharging into a watercourse or for any impact on watercourses

Source(s): The National Archives (2017)

2.7 Physical and technical interfaces

The 90 km Area North contract has been subdivided into smaller, geographical sections, called sublots, for ease of management. Figure 6 shows the key interfaces between and among the sublots, including interfaces with some key stakeholders.

Table 3 shows the number of key assets within each sublot.

The physical and technical interfaces between disciplines and with other stakeholders are managed as part of design development within each sublot. Technical interfaces management involves considering the requirements of each technical discipline and integrating it with the requirements of other disciplines. Figure 7 shows typical disciplines on the HS2 project.

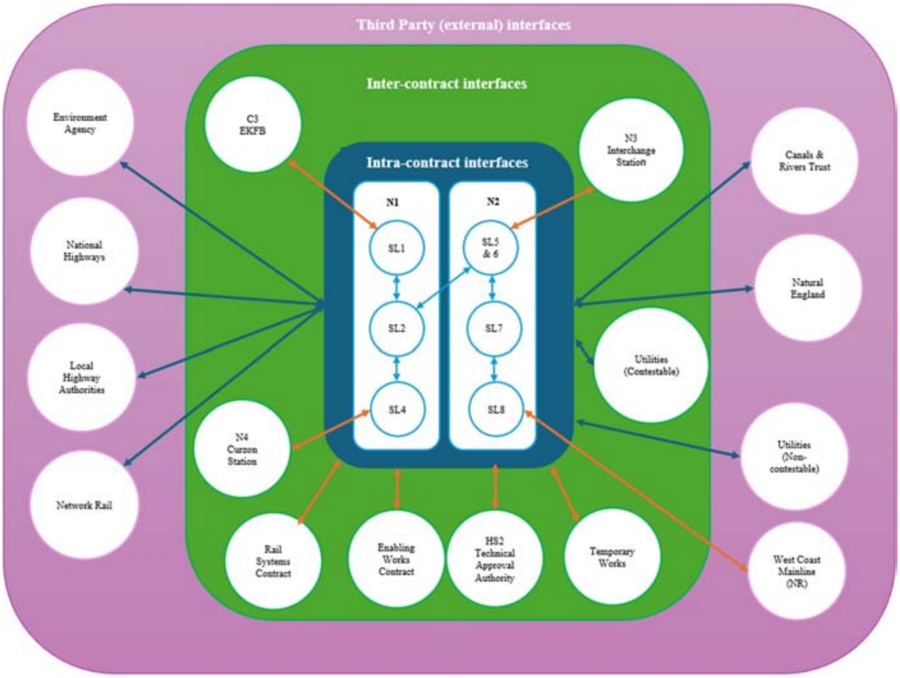

Figure 6. Key internal and external physical interfaces on Area North IPT. **Source(s):** Authors' own work

Table 3. Key assets in each sublot

Sublot no.	Tunnels	Viaducts	Overbridges	Underbridges	Embankments	Cuttings	Culverts
1	2						
2		8	25	4	21	15	40
4		4	2	2	2	2	4
5		3	7	5	6	3	9
6		17	3	3	10	3	3
7		4	8	12	11	8	21
8		5	14	6	11	4	42

Source(s): Authors' own work

The requirements of each discipline are specified in the following documents:

(1) HS2 Technical Standards

(2) Specification for Civil Engineering Works (SCEW)

(3) Other industry guidance and standards (such as Eurocodes, CIRIA (Construction Industry Research and Information Association) guidance, local authority design standards and many others)

The simplified design organisation chart in Figure 8 shows a typical technical delivery team for each sublot.

The interfaces within each sublot are managed through interface meetings that are held every fortnight. An interface register with details of each interface is kept for each sublot. This document captures all the interface issues/agreements and requests and is tracked regularly until issues are closed or resolved.

The sublot Engineering Manager is responsible for the overall technical delivery for each sublot. Design Managers are responsible for delivery of a package of works or assets within each sublot; sometimes further divided into geographical areas for ease of management. Technical Coordinators integrate the work of all the disciplines within each work package.

Conflicts in technical requirements are common. These are usually resolved through stakeholder engagement, discussion with the HS2 Technical Standard owners and following best practice guidance. The interface manager is part of the routewide Technical Directorate and is responsible for ensuring that all technical and physical interfaces are being managed appropriately.

Changes in standards are managed through a Technical Standards baseline, which is updated at preset intervals stated in the contracts. Where standards are not possible to implement this is managed through a departure process that needs to be approved by HS2 standard owners and/or the relevant stakeholders.

To ensure that the designs are compliant with the project requirements, technical assurance is undertaken within each sublot. The next section describes how technical assurance is carried out.

2.8 Technical assurance on HS2

Technical assurance is a "process by which the technical integrity of a product or system is progressively assured as it is developed, which is achieved by demonstrating that predefined processes have been correctly implemented and followed to meet the defined criteria." (HS2 Ltd, 2019).

Traditional Design and Build contracts in the UK usually require the design to be reviewed and approved by the client organisation before construction can begin. For the HS2 project, the client (HS2 Ltd) came up with an innovative approach to technical assurance whereby the

Figure 7. Typical technical disciplines within the scope of works. **Source(s):** Authors' own work

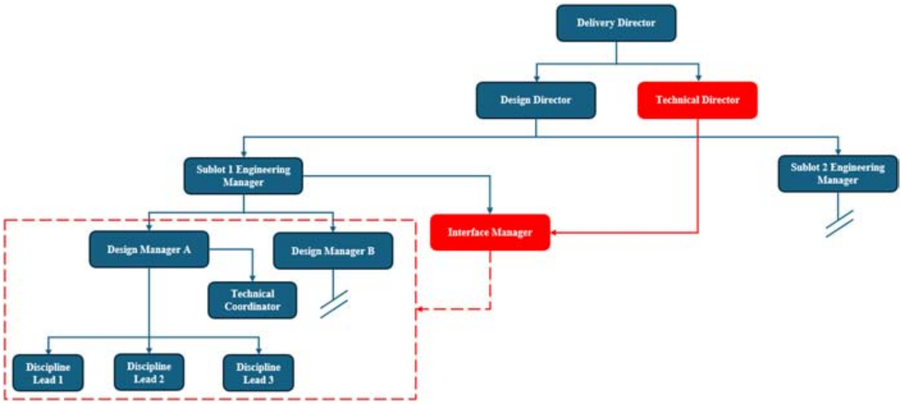

Figure 8. Organisational chart. **Source(s):** Authors' own work

contractors would self-assure and self-certify their own work. The client organisation adopted a risk-based approach where assets with high risk would be subjected to more thorough reviews while other assets would be selected for review depending on their risk profile. More complicated assets, such as long viaducts crossing motorways or with very long spans, would be reviewed in more detail than a simple culvert crossing a small ditch.

Alongside the development of the self-assurance approach, HS2 Ltd also introduced the concept of Integrated Project Teams (IPTs) across all the civil works contracts. In the Area North contract, the IPT is made of engineers, project managers and other technical experts from the Client (HS2 Ltd), the Contractor (BBV) and the Designer (Mott MacDonald/ SYSTRA DJV). Members from the three entities from each sublot work closely together in developing and reviewing the designs. Designs are also reviewed by relevant stakeholders, including the consent granting bodies to ensure that their statutory requirements have been incorporated in the design. The key function of the IPT is to carry out the progressive assurance of works; ensuring that designs and construction activities are interrogated and reviewed as the design/construction progresses rather than wait until the end of a design stage. This ensures that key interface issues are addressed as they develop and thus resolved early. Although alliances involving the client organisations, contractors, designers and other members of the supply chain are not new, the IPT concept on the HS2 project was unique in removing the traditional contractual barriers by allowing everyone to share information and ideas freely. Apart from bringing different project partners under one team within the IPT, the organisations themselves were also joint ventures partners. BBV itself was made up of British construction giant Balfour Beatty and VINCI, a French multinational contractor while the DJV was made up of UK based consultant Mott MacDonald and French railway consultant SYSTRA. The DJV had project members drawn from different parts of the world, thus bringing different expertise and cultural perspectives to the project. With this diversity and rich experience from different organisations, however, there was also a human interface which had a bearing on how the project was executed.

Figure 9 shows the makeup of a typical IPT for a sublot.

2.9 Constraints-led design

The route selection process for the high speed railway line between London and Birmingham followed very strict environmental and sustainability principles set out by the United Kingdom government. These principles included the need to reduce greenhouse emissions, combat climate change, protect natural resources and create sustainable communities, (Department for Environment, Food and Rural Affairs, 2005). As a result, the HS2 route corridor was selected

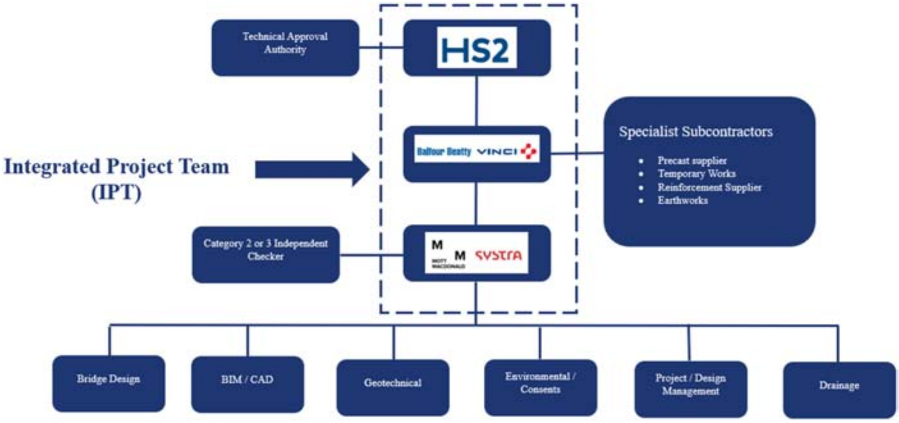

Figure 9. Integrated project team. **Source(s):** Authors' own work

so as to avoid or minimise, as far as was possible, adverse impact on existing housing and communities, landscape, water and ecological resources as well as historical or cultural resources (Department for Transport and HS2 Ltd, 2012). The United Kingdom is a comparatively small and densely populated country. Its geography and geology placed some constraints on the design and construction of HS2. Of the 225 km of the route between London and Birmingham, just under half (105 km) is under tunnels, with 20 km on bridges or viaducts and the rest on either cuttings or embankments. The route starts from the very urban and densely populated and built up area of central London, through the suburban outskirts of West London before cutting through the countryside, farmlands and areas of natural beauty of Buckinghamshire, Northamptonshire and Warwickshire. It then spurs left into the outer suburbs of Birmingham before terminating into the centre of Birmingham. Along its route the HS2 line crosses several rivers, valleys, Areas of Natural and Outstanding Beauty (AONB) – which are protected by law in the United Kingdom. The spur to the right which connects to the existing conventional West Cost Main Line passes through the semi-rural countryside of Staffordshire County.

To adhere to the government's environmental and sustainability principles, HS2 Ltd produced a landscape design guidance document (HS2 Ltd, 2016). The HS2 landscape design approach requires the new railway line to seamlessly integrate into the local landscape and minimise the negative environmental impacts of the scheme (Ombregt, 2025). As the landscape along the route changed the design of the surrounding environment had to reflect these subtle changes. In addition to the landscape guidance, HS2 Ltd also produced a Design Vision document. The HS2 Design Vision is centred around the core principles of people, place and time (HS2 Ltd, 2017). This means designing HS2 infrastructure for people to benefit from and enjoy (people theme), providing a sense of place with a coherent national narrative (place) and also providing a design that will stand the test of time and be adaptable for future generations (time). These constraints, in addition to the discipline-specific considerations had to be balanced against the requirements of internal and/or external stakeholders.

The case studies below look at particular examples on HS2 Area North where the different interfaces have been identified and the most efficient, considerate design solutions realised.

3. Case study 1: Lavender Hall heritage-listed barn – environmental interfaces

The proposed railway passes through or close to several buildings that are deemed to be of special architectural or historical interest. Such buildings are referred to as listed buildings. One such building, known as the Barn at Lavender Hall Farm, is located 100 m to the west of the HS2 track along Lavender Hall Lane in Berkswell, Solihull. Under the Planning (Listed Buildings and Conservation Areas) Act 1990, listed buildings must not be altered, extended or demolished without special permission. The Barn at Lavender Hall Farm (the barn) was identified early as a Grade 2 listed building that would be adversely affected by the construction of HS2 due to its proximity and semi-rural setting. It was noted that construction of the railway line and the adjacent Lavender Hall Lane would adversely affect the barn and its heritage status. Mitigation measures in the form of landscaping and earthworks bunds were proposed as part of the original scheme submitted at hybrid bill. These measures were included in the Environmental Statement and formed part of the Environmental Minimum Requirements (EMRs) that had to be satisfied at construction stage. Figure 10 show the location of the listed barn in relation to Lavender Hall Lane (highway) and the HS2 railway line. Plate 2 shows the photographs of the barn.

During detailed design development, the vertical profile of the adjacent highway had to be raised and the road had to be moved closer to the barn in order to make it compliant with the highway design standards following a revision of the highway design speed (Figure 11).

Raising the profile of the road and shifting it closer to the barn had the unfortunate impact of further adversely affecting the heritage status of the listed barn beyond what was noted in the Environment Statement. Further surveys carried out at detailed design also revealed that the barn foundations were very weak and any excessive vibrations during construction or operation could seriously undermine the structural integrity of the barn potentially leading to its excessive damage or even collapse. Any damage to the building would constitute a breach of the EMRs.

As a result of this, the design team working closely with the Contractor (BBV) and other stakeholders came up with design solutions to ensure that the heritage status of the barn was not affected.

(1) Due to the proximity of the highway to the barn building, a retaining wall solution was recommended. Several types of retaining walls were considered, but most were discounted because they would require excavation in front of the barn. After discussions with specialist subcontractors a crib wall solution was proposed and adopted. A crib wall is a type of retaining wall, specifically characterized by being built using interlocking, box-like frameworks, called “cribs,” that are filled with granular materials like soil or rock. It requires shallower foundations thus removing

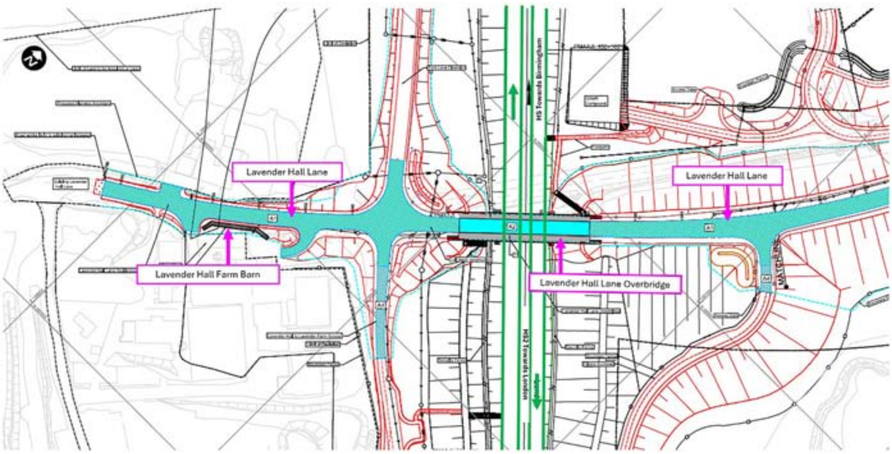

Figure 10. Location of the listed barn at Lavender Hall farm. **Source(s):** Authors’ own work

Plate 2. Listed barn at Lavender Hall farm, view from south (left) and view from north (right). **Source(s):** Authors' own work

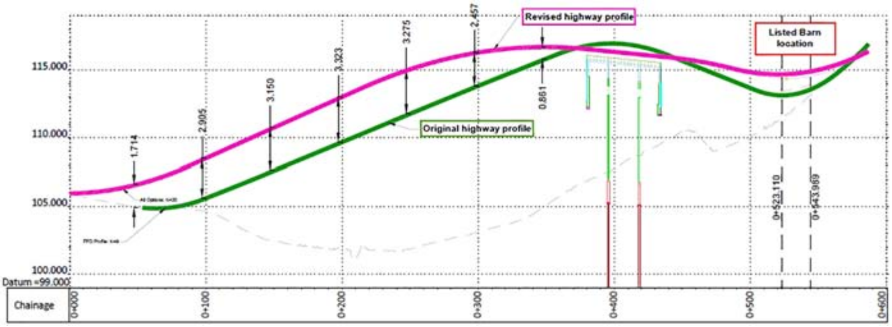

Figure 11. Comparison between the original and the revised vertical profiles of Lavender Hall lane. **Source(s):** Authors' own work

the need for deep excavations close to the susceptible barn foundations. The local highway authority, who would maintain the road, were receptive to this proposal.

(2) To further minimise disturbance to the barn, a precast supporting beam was placed on a 10 m section of the crib wall that was closest the barn foundation. The beam had pad foundations on either end which would take all the eight of the beam.

(3) The geotechnical engineers carried out a ground movement assessment to analyse the impact of construction vehicles and operational traffic on the barn. The assessment resulted in the embankment fill material under the highway being changed from Class 2 to Class 6C material. Class 6C material is uniformly graded material while class 2 is aggregate material (National Highways, 2017). Class 6C was chosen as it can be easily compacted with a smaller vibratory roller compared to Class 2 material made up of aggregate material. Figure 12 shows the highway embankment fill material in relation to the barn and the crib wall.

(4) To maintain the character of the area, some planting was proposed on the crib wall and surrounding area. The planting was made from local species from the area so that it would easily blend. A typical planting scheme would be as shown in Plate 3.

Through a collaboration between the disciplines and with key stakeholders, the design team was able to propose an acceptable solution for this section thus complying with the EMRs, the

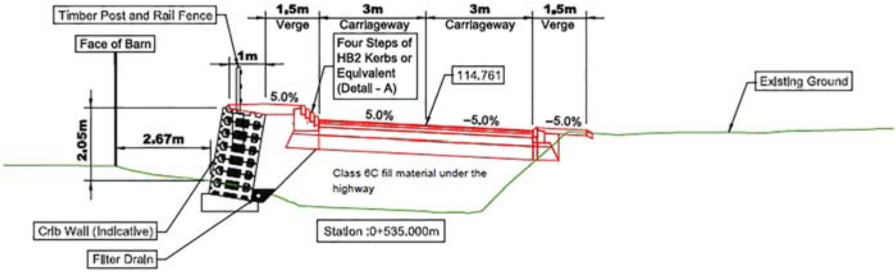

Figure 12. Section showing location of crib wall and Class 6C highway embankment fill material. **Source(s):** Authors' own work

Plate 3. Showing typical planting on crib wall. **Source(s):** Authors' own work

HS2 Landscape Design Guidance and complying with the Planning (Listed Buildings and Conservation Areas) Act 1990. The design was accepted by the local highway authority in line with the HS2 Act provisions.

4. Case study 2: highway interface at motorway crossings

National Highways operates and maintains the strategic route network (SRN) in the UK. The SRN includes motorways and major roads, known as A-roads. At the northern end of the HS2 railway line, the high speed railway crosses the M6 and the M42 motorways and other major A-roads at several locations. The railway line also crossed local roads (managed by local highway authorities). existing railway lines (managed by Network Rail) rivers and floodplains (managed by the Environment Agency) and canals (managed by the Canals and Rivers Trust). Figure 13 shows one example of these locations – the Delta junction, where the HS2 splits into two – with one section connecting to the terminal station at Birmingham Curzon Street while the other section continuing further north to join the conventional railway line on the West Coast Mainline (see Case Study 3).

4.1 Interface challenges associated with working on the strategic route network

(1) The Design Manual for Roads and Bridges (DMRB), owned by National Highways, is the definitive design standard used on all highway projects in the UK, including local roads. However, on the HS2 project the DMRB had to be supplemented with other HS2 Technical Standards to cover for additional requirements for high speed rail.

Figure 13. Motorway and highway crossing points for HS2 (red circles). **Source(s):** New Civil Engineer (2024)

Coordination with the technical teams of both organisations was necessary to understand how the different design standards were to be implemented.

(2) A typical National Highways project to install a new bridge or viaduct crossing an existing motorway could take 2 to 3 years, including planning, design, procurement and construction. Some more complicated works could take slightly longer, but nowhere near the more 10 years it took for HS2 to start planning stages until construction started on site. During this time the design standards had been amended and updated several times, including a major overhaul and rewriting of the DMRB in 2019–20. The designers on Area North contract had to review the designs against the new standards to ensure they were still compliant and that there were no safety implications. In many case the designs had to be amended to comply with new standards, as noted in Case Study 1.

(3) National Highways is funded by the DfT, just like HS2 Ltd. National Highways is usually the client on all works affecting the SRN. However, for works on HS2, National Highways was instead just another stakeholder with most of its usual powers transferred to HS2 through the HS2 Act. National Highways is also very established, with its processes and procedures more mature than those of HS2 Ltd, which was only created for the promotion of the HS2 project. This perceived dilution of National Highways's powers was an organisational interface that had to be resolved at higher levels of management to ensure alignment of goals.

(4) The need to get consent before construction could begin was one of the biggest interface challenges on this part of the project. Although the HS2 Act requires consent granting bodies like National Highways to provide consent within a stipulated time frame and not to "unreasonably withhold" consent, in practice the process of getting

consent took longer. Several pre-application and design progress meetings were required with National Highways and other local highway authorities, and often these meetings resulted in more changes being required to the design. Due to the novelty of using the HS2 Act for delivery highway works rather than the usual Highways Act (1980), many National Highways and local highway authority officials were not aware that most of their powers had been transferred to HS2. As noted in (Taivo, Graves, & Hawley, 2022) the responsibility for informing the local authority officials of the provisions of the new HS2 Act fell on HS2 and its supply chain, which in practice meant the DJV's engineers and planning managers. Engineers had to quickly study the relevant HS2 Act schedules and provisions and understand them first before explaining to sceptical highway officials. Getting trust from consent granting bodies therefore took longer than had been anticipated.

(5) Design iterations following consultations with highway authorities also took very long, and it became clear that it would not be possible to keep to the construction programme if consent was a prerequisite for starting construction. As a result of this the IPT proposed a staged assurance and construction approach whereby works would be carried out in stages, with consent being granted for each stage of the construction rather than for the whole asset. For example, a bridge would be divided into three distinct stages DD1 (for foundations elements like piles and pile caps), DD2 (for piers, abutments and wingwalls) and DD3 (for decks, beams for the deck, parapets and diaphragms depending on the type of structure. The corresponding construction stages were designated as IFC1, IFC2 and IFC3. To help speed up the internal technical assurance within the IPT, the design was interrogated as it progressed rather than wait to the end of each design stage. This is illustrated in Figure 14.

(6) The staged assurance was an improvement on the progressive assurance approach already introduced by HS2 Ltd. This innovative approach to design and construction assurance became an exemplar on the project and was adopted in other Main Works Civils Contracts.

(7) The large number of motorway crossings in close proximity to each other meant that their construction would disrupt the flow of traffic on the major motorways for several years. To minimise this, the designers and BBV came up with some innovative construction methodologies to speed up construction and minimise interruptions. These were discussed collaboratively with National Highways and other key stakeholders such as Network Rail, Canals and Rivers Trust, utilities companies and

Progressive Technical Assurance, Staged Construction

- Design and Construction split into three stages
- Close cooperation between DJV, Contractor and specialist subcontractors to ensure design was buildable and to review and implement supply chain requirements into the design

Element	Detailed Design	Construction
Foundation and slabs for the box structure and wingwalls	DD1	IFC1
Abutments, box walls and wingwalls	DD2	IFC2
Precast T-beams, deck slab, diaphragm and precast parapets	DD3	IFC3

Figure 14. Staged construction and progressive technical assurance. **Source(s):** Authors' own work

the Environment Agency. Some of the examples of construction innovations are discussed below:

- Six of the motorways crossing viaducts were built as Precast Segmental Viaducts (PSV) (Figure 15). The viaducts are produced offsite in purpose-built factories and assembled on site using cantilever construction. The segments, with predefined lengths, also come with post-tensioned cables and grouted tendons which help to incorporate temporary works into permanent works thus helping to minimise construction time. PSVs had not been used on UK motorways for several years due to their complexity and this method was also not covered under the existing DMRB standards. However, the VINCI team of Contractor BBV and the SYSTRA side of the DJV had expertise of successfully using PSVs in other countries, particularly in France where both VINCI and SYSTRA are headquartered. This innovative approach to construction was accepted by National Highways and will be incorporated into the National Highways standards at their next major revision.
- The use of the "push-pull" technique to launch the four sections of the M42/M6 Link East and West Viaducts was another innovative construction methodology that had not been used in the UK before but is likely to become the standard. Using this method, the steel decks were moved into place by a special pulley system that guided them into the piers in the central reservation of the motorway, which had been constructed in advance. The decks could be moved backwards, forwards or even sideways until they were in the precise coordinates required. This flexibility meant the process of launching the decks were faster; the motorways were only fully closed for less than 48 hours in for each crossing (New Civil Engineer, 2024). This meant there was reduced disruption to traffic. Plate 4 shows photographs of the "push-pull" launch over the motorways.
- The 12,600 tonne Marston Box (Plate 5) over the M42 motorway was moved into place in under 40 hours. The sliding mechanism used allowed the bridge to be pushed over the motorway on a guiding raft of nearly 165 m, which HS2 believes to be the world's longest box slide of its type (HS2 Ltd, 2022). The box structure was constructed just on the side of the motorway thus reducing traffic interruption and the amount of construction vehicles that would have been required to bring precast elements from factories away from the site. The box sliding mechanism had never been used by National Highways before as most of the bridges were constructed in situ. However, it became necessary on the HS2 project due to the number of such structures required and the need to minimise motorway closures and disruption to traffic. Since the box slide on the Marston Box in December

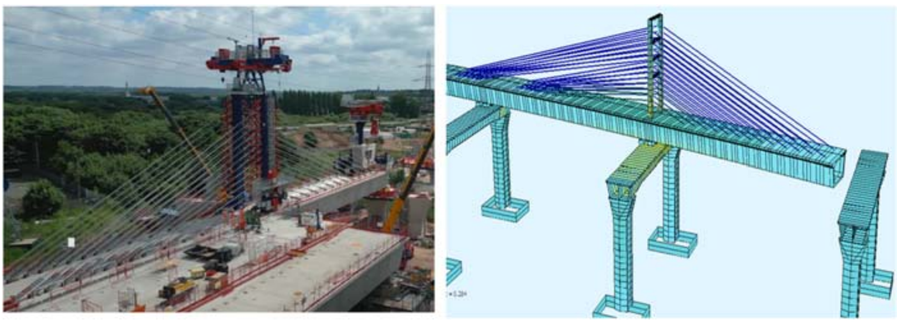

Figure 15. Precast segmental Viaduct with temporary cable stay mast (left) and in a BIM model (right)

Plate 4. M42/M6 link Viaduct launch using push/pull technique. **Source(s):** HS2 Ltd (2024a, b, c)

Plate 5. M42 Marston box sliding over the motorway. **Source(s):** HS2 Ltd (2022)

2022, BBV and the DJV have used this technique on more than a dozen other crossings within the Area North contract. The approach has also been adopted by other contracts on the wider HS2 project.

5. Case study 3: interface with the conventional railway network – Fulfen Wood and Streethay overbridges

5.1 Overview

Network Rail is the owner and infrastructure manager of most of the conventional railway network in Great Britain. Like HS2 Ltd, Network Rail is a non-departmental public body of the DfT. The HS2 tracks cross the existing conventional railway network at several locations in the Area North contract. In Sublot 8, Network Rail crosses the West Coast Mainline (WCML) at

Fulfen Wood and the South Staffordshire Line at Streethay, in Staffordshire. Both lines are owned and managed by Network Rail. The WCML is one of the busiest mixed use railway line in the country while the South Staffordshire Line is a non-electrified line carrying mainly freight but with some passengers across the West Midlands. In order to allow for HS2 to cross both lines, which are 1 km apart along the line, temporary possessions of the lines were required. A possession is a temporary exclusive control of a section of the railway network to allow for a safe, traffic free environment to carry out construction work, maintenance or renewals without risk of collision with trains (Network Rail, 2019). The constraints for each location are discussed below.

5.2 Fulfen Wood overbridge

This overbridge was required to take HS2 under the WCML. The constraints for the site were as follows:

(1) Only a maximum nine day possession of the WCML was permitted to minimise disruption to passengers on this very busy route.

(2) Exclusion zones around the existing railway prevented any construction works being carried out within a certain distance from the railway corridor. This was to ensure that the structural integrity of the existing track bed was not undermined.

(3) Existing utility services and cables, including 400 kV Extra High Voltage overhead cables within the site which had to be protected/avoided throughout the works

The small possession window available required designers and the construction teams to find a method that would maximise the available time. One of the two options considered was the use of the jacking method. This entailed lifting the bridge using hydraulic jacks to place it into position. The advantage of this method was that it would enable to full monolithic bridge to be placed into position in one go. However, this would take at least two days out of the nine available thus leaving little time for other activities. The second option was to use a Self-Propelled Modular Transporter (SPMT) to lift and drive the bridge into position. This would require the bridge to be adapted to a portal structure during the rail possession. However, the operation would be completed in a few hours. This had a huge benefit for construction by significantly increasing the time available for reinstating the railway and de-risking the construction programme. By temporarily propping the structure, the base slab for the bridge could be cast after the rail possession without programme pressure.

By understanding the constraints of the works, and by working closely with Network Rail, BBV and DJV were able to provide a bridge structure that satisfied HS2 requirements without compromising any of Network Rail's requirements. The use of the SPMT was a huge success which showed innovation as the 6,200 tonne bridge was moved in less than one hour with huge savings on the construction programme. So successful was this methodology that it was repeated on the Streethay overbridge which is just 1 km further up the line.

Plates 6–9 show Fulfen Wood Overbridge being placed into position using the SPMT.

5.3 Streethay overbridge

The South Staffordshire Line has a low frequency of trains, but it is an important diversion route between Birmingham and the North West of England. Unlike the Fulfen Wood Overbridge, this route could afford to be closed for longer, so Network Rail approved a 77 day possession to allow construction of the new overbridge. The initial designs showed a cast-in-situ integral bridge within an earthworks cutting made from secant piles. However, as the design developed there were other constraints which meant that it would not have been possible to complete the works even within the long 77 day possession. The constraints included the following:

Plate 6. Fulfen Wood overbridge in position during possession and backfilling underway. **Source(s):** HS2 Ltd (2023a)

Plate 7. Fulfen Wood overbridge with SPMT lifting and positioning bridge. **Source(s):** HS2 Ltd (2023a)

Plate 8. Fulfen Wood overbridge with temporary props in place and corbels being removed. **Source(s):** HS2 Ltd (2023a)

Plate 9. Fulfen Wood overbridge in position during possession and rails being replaced. **Source(s):** HS2 Ltd (2023a)

(1) Constructing 76 27-m deep secant piles

(2) Initially excavating 3,000 tonnes of earthworks and then backfilling 300 tonnes of earthworks after placement of the bridge

(3) Casting a single 930 m^3 concrete pour for the deck

(4) Placing 670 tonnes of reinforcement

(5) Undertaking seven utility diversions and reinstatements

(6) 170 m of track removal and reinstatement

The constraints above prompted the designers to change the structure from cast-in-situ to an offline construction and using SPMTs to transport the 2,500 tonne bridge into position. Using the lessons learnt at the Fulfen Wood Overbridge the design team managed to complete the works within the possession time allowed. Plates 10–12 show the construction and placement of the Streethay Overbridge into place.

5.4 Summary

The use of SPMTs played a big part in completing both works at WCML and South Staffordshire Line within the possession time allowed. Although this technology is not new, it

Plate 10. Streethay overbridge construction on temporary supports to allow SPMTs to lift bridge from underneath. **Source(s):** HS2 Ltd (2023b)

Plate 11. Streethay overbridge simply supported whilst temporary supports are removed. **Source(s):** HS2 Ltd (2023b)

Plate 12. Streethay overbridge in position and track replaced. **Source(s):** HS2 Ltd (2023b)

has not been used extensively in the UK due to geographical and site constraints, and also because such extensive works affecting the existing railway have not been required. The IPT worked collaboratively with subcontractors to use the same SPMT equipment for both locations thus benefitting from economies of scale and lessons learnt. The IPT also worked closely with Network Rail engineers to understand the interfaces and constraints. Network Rail, as an established organisation, has very robust and established design assurance processes in place; these were used alongside those of IPT to ensure that there was no duplication of effort.

Plate 13 shows the nearly completed two overbridges in their respective final locations.

6. Conclusions

Interface management is the systematic coordination and management of communications, roles and responsibilities amongst various contracted parties and stakeholders on a project. This enables project goals to be aligned and facilitates the successful execution of projects. Interface management is particularly important on large infrastructure projects, such as high speed rail projects, which have several contractors, an extensive supply chain, span across several years of construction and cost billions of dollars. This paper has presented interface

Plate 13. Fulfen Wood (left) and Streethay (right) overbridges in place during their respective possessions.
Source(s): HS2 Ltd (2023a, b)

management approaches based on three separate case studies from the HS2 project in the UK. The main conclusions are:

(1) On the HS2 railway line in the UK, Interface management was particularly important in dealing with some of the unique project complexities. The regulation of the HS2 project was through a very complicated hybrid bill process which is rarely used on other construction projects. The requirement to obtain the consent and approval from some of the key stakeholders before construction prompted the IPT to seek ways of improving project delivery. The project is also delivered via a succession of several large contracts rather than few catch-all contracts, which added to the complexity of Interface management. Without a robust interface management system in place, it would have been very difficult to manage a project of this size and complexity.

(2) The United Kingdom is a relatively densely populated country, with heavily built up urban areas and a countryside that is heavily regulated by very strict environmental protection laws. To comply with the law, the design of HS2 has to be sensitive to the changing surroundings along the route. These geographical and regulatory constraints led the IPT on the Area North contract of the HS2 project to develop innovative design and construction methods. The IPT was able to optimise the use of resources on the project, minimise duplication of roles and avoid costly and endless design reviews by bringing all the relevant stakeholders early in the design process. Progressive technical assurance allowed stakeholder comments to be incorporated early in the design and thus reduce the occurrence of costly design changes. This shows that interface management is an integral part of project management.

(3) Through three separate case studies, the paper has shown how environmental interfaces were managed to ensure compliance while not compromising the construction schedule. The case study on launching viaducts across a busy network of motorways showed how innovative design and construction approaches were brought for the first time in the UK construction industry – a direct result of the need to comply with strict requirements of a key stakeholder. The final case study on working on the existing railway network showed the need to accelerate construction by using modern methods of construction which were not the norm in this industry before. Although each separate case study had its own challenges, a recurring them across the three case studies was the need to coordinate and communicate with all the stakeholders throughout the design process – an essential ingredient of successful interface management.

(4) This paper has employed the case study methodology to get an in-depth understanding of how interface management was used on one project – with separate case studies explored in greater detail. The authors were project participants in the process, and this gave them access to various sources of data. While the case studies provided valuable insights on the importance of interface management on complex projects such as high-speed rail, it is not possible to generalise the findings based on such a limited and unique data set. The authors being project participants could also have led to unconscious bias in the discussions of some of the findings. Thus, there is scope for more studies on similar projects to provide more examples and contribute to the growing body of research on interface management on construction projects in general, and high-speed rail projects in particular. Further research would help in identifying how proactive stakeholder management can lead to positive outcomes, particular on complex construction megaprojects.

(5) Notwithstanding the above shortcomings, the experience from the HS2 project has shown that by working collaboratively early in the design stages and throughout the project, high speed rail projects can be delivered in a way that addresses the major concerns of key stakeholders.

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