HS2 Project Specification

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List of acronyms

EMC	Electromagnetic Compatibility
EPS	Enhanced Permissible Speed
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
FMECA	Failure Modes, Effects, and Criticality Analysis
GSM-R	Global System for Mobile communications - Railways
IEP	Intercity Express Programme
Kph	Kilometres per hour
OHLE	Overhead Line Equipment
R&M	Reliability and Maintainability
tph	trains per hour
TSI	Technical Specifications for Interoperability

1 Introduction

1.1.1 This document identifies the key technical, operational and environmental requirements that need to be defined and subsequently met by High Speed 2 (HS2). During this early project phase, this specification is intentionally not comprehensive in all areas; the requirements identified are those which are pertinent to enabling achievement of the HS2 project deliverables, as defined in the exchange of letters between Sir David Rowlands and Lord Adonis in 2009.[1]

1.2 Technical Specifications for Interoperability

1.2.1 The EU Technical Specifications for Interoperability (TSIs) mandate the specifications which must be met by all new high speed lines and their connections to the classic rail network. As a result, many requirements identified herein are taken directly from the relevant TSIs. In designing and developing HS2, the following hierarchy has been followed - TSIs have taken precedence but in areas not thus defined, current UK legislation and national standards have been applied and thereafter either anticipated or current accepted "good practice" adopted. The business advantages of creating a TSI compliant high speed railway are set out in section 2.3 of our report to Government in December 2009[2].

1.3 Safety

1.3.1 HS2 seeks to deliver a safe and reliable railway system throughout its design, construction, operation and maintenance. It is recognised that HS2 is likely to operate at maximum linespeeds higher than those currently employed in the UK. Whilst the consequences of any incident at high linespeed can be severe, HS2's primary aim will be to specify and design out safety risk to prevent incidents occurring in the first place. If safety risk cannot be eradicated, it will be mitigated as far as is reasonably practicable.

1.3.2 Key risks and potential measures have been identified as shown below; measures are being translated into HS2 requirements within this specification:

- collision risk (other train / structure) - train control systems and structures specification / use of grade separated junctions;
- derailment risk (obstruction on line / track design / track quality) - no level crossings; appropriate derailment containment measures; appropriate pedestrian fencing / vehicular barriers; review of access points and associated maintenance strategy; track specification and maintenance;
- risks to passengers on trains - avoidance of collision and derailment risks as above;

[1] "Objectives and remit for HS2" letter from David Rowlands, Chairman of HS2 to Lord Adonis dated 13.02.09 and subsequent response from Lord Adonis dated 09.03.09

[2] "High Speed Rail London to the West Midlands and Beyond: A Report to Government by High Speed Two Limited" December 2009

train crashworthiness and fire hardness; consideration of luggage handling measures and seatbelts; appropriate step-free access;

- mixed traffic - HS2 policy is for no mixed traffic (passenger and freight) operation;
- safety in tunnels - specific measures for individual tunnels depending upon design and in line with the TSI relating to safety in railway tunnels;
- safety of maintenance staff - separation of maintenance activity from train operations; automation of inspection and maintenance activities;
- adverse weather conditions e.g. flooding, storms, crosswinds - appropriate measures to be considered when line of route is established;
- stations (evacuation / personal security / trains passing) - specific measures for individual stations depending upon design; consideration of platform screen doors; provision of platforms off high speed through lines; and
- security - appropriate anti-trespass and anti-vandalism measures; security measures at rolling stock depot / stabling facilities and stations.

1.3.3 The safe operation of the overall HS2 system will only be delivered by consideration of 'soft' as well as 'hard' factors. In due course, soft factors for example the selection; education and training of operations and maintenance staff will also need to be considered fully.

1.4 HS2 services

1.4.1 The core HS2 route between London - West Midlands will be used by two types of service from Day 1:

- High speed captive services operating between London and Birmingham using standard European TSI compliant high speed trains. These are referred to as "captive" trains.
- Services running between London and destinations north of the West Midlands, using specially designed and manufactured high speed rolling stock capable of traversing the UK classic rail network. These are referred to as "classic-compatible" trains.

1.4.2 The sections covering operational, rolling stock and performance requirements reflect this as needed.

2 Operational requirements

2.1 Operating hours

05.00 - 23.59 Monday - Saturday

08.00 - 23.59 Sunday

2.2 Maintenance and engineering hours

00.00 - 05.00 Monday - Saturday

00.00 - 08.00 Sunday

The operation of high-speed services and maintenance / engineering activities on any track shall be segregated. Where work can be fully enclosed then it may be permissible on one track with adjacent tracks open subject top appropriate restriction of speed on the open tracks and available timetable capacity.

2.3 Train service specification

2.3.1 Passenger capacity

The project shall assume a train capacity of up to 550 people per 200m high speed service. For captive train services only, two 200m trains may be coupled together to give a capacity of 1,100 people.

2.3.2 Line capacity

For services in phase one, the project shall assume a maximum utilisation of up to 14tph during the high peak periods with a typical utilisation of 10tph during the day, so allowing for the relative reliability of dedicated high speed services and those running on to the classic network and existing documented train control system and train braking capability.

The project shall assume an ultimate capacity of 18tph based on longer term high speed network with services largely segregated from the classic network and anticipated improvements in train control systems and train braking technology.

2.3.3 Station capacity

Longer term passenger demand shall be assessed in terms of numbers entering, leaving and interchanging and shall be used to develop the station design and safety case.

Design of any station for international traffic shall make provision to segregate international outbound and inbound passengers from UK domestic passengers and carry out security and customs procedures required by UK Border Agency.

2.3.4 Passenger service frequency

Phase one service assumptions to be used for demand modelling for the core HS2 route are shown below:

Service		**Journey Time (mins)**	**Off-Peak Pattern (tph)**	**Peak Pattern (tph)**
From	**To**			
London	Birmingham	49	3	4
London	Manchester	100/ 104	3	3
London	Liverpool	110	2	2
London	Preston	110	1	1
London	Glasgow (via Preston)	240	1	1

2.3.5 Stations to be served

The HS2 stations to be served in phase one are detailed below.

Station to be served	**Comment**
London Terminus	Service growth beyond phase one to be considered in developing station footprint due to high likelihood of subsequent extreme access constraints.
Outer London / Heathrow / Crossrail Interchange	Assumed all HS2 services will stop here
Birmingham Interchange	Not all services will stop here, platform faces will be off the fast through lines
Birmingham Terminus	Service growth beyond phase one to be considered in developing station footprint

2.3.6 Platforming of trains

The project shall make provision for accommodating two 200m train units coupled together.

The project shall make provision for an appropriate number of platform faces at terminal stations served on the basis of a minimum of one platform face per two trains per hour.

Assess the requirement and demand for an intermediate or interchange station in the West Midlands.

All HS2 station platforms shall be equipped to permit joining and splitting trains within the platform.

2.3.7 Crossovers

For the purpose of estimating costs, the project shall assume provision of open-route crossovers for operational flexibility and engineering access requirements nominally at every 20km along the route, where crossovers are not already provided for other reasons.

The need for recess loops for operational flexibility and engineering access requirements is to be determined.

Connections to the classic network shall be determined by service business need or infrastructure maintenance practicality.

2.3.8 Depots and stabling

The project shall assume the provision of one main rolling stock maintenance depot to service rolling stock required for the operation of high speed captive and classic compatible train fleets in phase one.

The main depot (to point of stabling) shall be no more than 10 minutes journey time from the HS2 route.

The project shall determine the requirement for additional rolling stock stabling and servicing facilities necessary to support HS captive and classic compatible trains for phase one services.

The project shall assume the provision of one main infrastructure maintenance depot mid-route for HS2 infrastructure. This depot shall be capable of stabling on track plant and all necessary spares to enable all maintenance activities to be undertaken.

The project shall determine the requirement for any additional out based maintenance and on track plant stabling facilities.

2.4 Freight capability

The project shall evaluate the potential costs and benefits associated with providing freight capability on the high speed route.

The project shall design the route horizontal and vertical geometry plus civil engineering support structures to values which do not preclude conventional freight service operation over HS2 should the business requirement materialise.

No active or passive provision shall be made for freight specific junctions additional to those required for passenger operation, maintenance and stabling.

No additional requirements shall be added to the design of safety in tunnels to permit future conveyance of dangerous goods.

2.5 Futureproofing

The project shall evaluate the potential for future proofing through comparison of the cost of providing future capability now versus future retrofitting.

The project shall evaluate the passive provision of four tracks.

3 Rolling stock characteristics

3.1 Captive high speed passenger rolling stock parameters

Definition of the parameters shown below is being informed by development of an HS2 reference train.

High speed captive rolling stock parameters shall be defined to satisfy the requirements provided below:	
a)	dynamic reference contour - UIC vehicle gauge GC;
b)	train length - maximum train length 400m (2 x 200m units running in multiple);
c)	maximum average acceleration - as defined in the HS2 reference train acceleration data;
d)	minimum commercial operating top speed - 360kph;
e)	braking deceleration - as defined in the HS2 reference train braking deceleration data;
f)	axle loads - maximum permissible axle weight of 17 tonnes;
g)	regenerative braking - in line with TSI requirement;
h)	tilt - not required;
i)	noise - in line with TSI requirement;
j)	passage through tunnels - train will be sealed and pressurised with time constant 10 seconds;
k)	EMC - in line with TSI requirement;
l)	stepping arrangement - compatible with 760mm platform heights; and

m) accessibility for persons of reduced mobility - in line with TSI requirement.

3.2 Classic compatible high speed passenger rolling stock parameters

Classic compatible high speed rolling stock parameters shall be defined to satisfy the requirements provided below whilst operating on the high speed network.

a) dynamic reference contour - UK1 Gauge (i.e. suitable gauge to enable this stock to call at stations on the classic network without substantial station platform modifications);

b) train length - maximum train length 200m;

c) maximum average acceleration - as defined in the HS2 reference train acceleration data;

d) minimum commercial operating top speed - 360 kph;

e) braking deceleration -as defined in the HS2 reference train braking deceleration data;

f) axle loads - maximum permissible axle weight of 17 tonnes;

g) regenerative braking - in line with TSI requirement;

h) tilt - not required;

i) noise - in line with TSI requirement;

j) passage through tunnels - train will be sealed and pressurised with time constant 10 seconds;

k) EMC - in line with TSI requirement but also compatible with legacy systems on classic routes, including those adjacent to HS2 lines;

l) stepping arrangements - provision to enable passengers to safely alight or board at platforms of TSI or UK standard design (e.g. platform heights of 760mm and 915mm respectively); and

m) accessibility for persons of reduced mobility - in line with TSI requirement.

Classic compatible high speed rolling stock parameters shall be defined to satisfy the requirements provided below whilst operating on the classic network: to be determined

3.3 Compatibility with classic network

Additional features which require consideration to enable trains running off the high speed network on to the classic network include the following:

- Train Protection Warning System / Automatic Warning System;
- areas of enhanced permissible speed (use of EPS and gauge considerations)
- overhead line equipment (OHLE) power sufficiency;
- platform gauge, heights and lengths;
- route availability;
- pantograph compatibility;
- position and length of neutral sections (relative to position of train pantograph);
- wheel and rail profile interface;
- signal sighting;
- GSM-R standard;
- selective door operation;
- compatibility of magnetic brakes; and
- regenerative braking

4 Infrastructure requirements

4.1 Line of route footprint

The project shall assume a two track fence to fence trace width of up to 22m for an at-grade railway.

The project shall undertake an assessment of vegetation along the perimeter of the proposed line of route in conjunction with third parties to assess the impact of “leaf fall” on the proposed operation of the railway and to determine the extent of any additional land clearances or permanent easements that may be required.

Where space is restricted, the minimum two-track fence to fence width may be reduced from 22m to 15m. This reduction shall only be accepted exceptionally for short distances where no other solution is viable. The corridor width of 22m should be retained to allow for the inclusion of access tracks etc.

4.2 Track

The project shall assume the minimum number of tracks to be two.

The project shall assume a maximum line speed of 400kph where topographical, train performance and sustainability issues permit.

The line shall be designed to permit trains to maintain consistent high speeds.

The project shall assume that the track category will be one as defined in the TSI.

The project shall assume use of ballasted track except in tunnels where slab track shall be assumed.

The distance between rails for design purposes shall be 1,435mm.

At the design stage, the spacing between track centres is dependent on the design speed at any given point and is a function of the aerodynamic effects of two trains passing and the physical kinematic envelope. The TSI sets out the minimum spacing of tracks up to a maximum line speed of 300kph. For speeds in excess of 300 kph the TSI does not define the minimum track spacing though it is recognised that as speed increases so the pressure between two passing trains increase. The spacing of tracks above 300 kph shall be set as:

301 – 350 kph – minimum 4.5m

351 – 400 kph – minimum 5m

The project shall assume an absolute maximum cant of 180mm. The project should only design to these limits in exceptional circumstances.

The project shall limit cant deficiency rules as shown in the TSI. The project shall not exceed normal maxima (i.e. 100mm for speeds up to 300 kph inclusive and 80mm for over 300kph) and shall not routinely design to the limit.

The minimum radius of curvature shall be determined on the basis of linespeed, cant and cant deficiency applied.

Transitions between straight and curves or successive curves shall be established in the form of a clothoid.

The maximum vertical acceleration experienced due to the effect of vertical curvature shall normally be 2.25% of g. Under exceptional circumstances, this can be increased to 4.25% of g.

Vertical and horizontal curves shall not be overlapped nor their transitions.

The maximum vertical curve radius shall be 40,000m.

The length of a vertical curve and the length between two vertical curves shall not be less than Lm = V/2.5, where Lm = minimum length of curve in metres and V is velocity in kph. The minimum length of curve shall be 100m.

Vertical curves shall be provided if change in gradient exceeds 1mm / m.

The rising and falling gradients of the new high speed line shall be limited to a maximum of 35% (for exceptional use and for a maximum length of no more than 6,000m); typically gradients should be less than or equal to 25%.

The project shall assume swing nose crossings will be installed on the high speed line.

The project shall assume turnout speeds of 230kph maximum. High speed crossovers shall only be installed on straight track sections and on consistent / flat gradients.

The project shall assume the minimum entry / exit speed at platform ends to be 80kph at complex terminal locations.

4.3 Civils

The minimum gauge of the infrastructure shall comply with the reference kinematic profile GC.

Structures shall be designed in accordance with the loading requirements of the TSI, allowing for 25.5 tonne axles to be carried. High speed train axle loads of 17 tonnes shall be used for life cycle and fatigue calculations.

Surface and ground water drainage shall be provided so as to ensure that water levels do not rise to a level closer than one metre below rail level. The route shall be designed to ensure the safe operation of trains during a 1 in 1000 year flood event.

When calculating the required tunnel cross-sectional areas, the following data should be assumed:

- train cross-sectional area 12 sq m;
- sealed trains with time constant 10 seconds;
- train friction coefficient 0.003;
- the criteria should be met for trains of 200m and 400m.

The maximum pressure variation in tunnels as measured at any point on the outside of the train shall not be more than 10 kPa. In the case of two-track tunnels, this criterion shall be met for all possible timings of two trains entering the tunnel including worst cases that might occur only rarely.

The maximum pressure variation in tunnels as measured at any point inside the train shall not be more than 0.5kPa in any one second period and not more than 2.5kPa in any 10 second period. For two-track tunnels, these criteria must be met for at least 95% of possible timings of two trains entering the tunnel. For the remaining 5% of possible timings, it will be permitted to exceed these pressure limits by up to 40%.

For tunnels over one kilometre; the project shall comply with the TSI relating to ‘safety in railway tunnels’.

The project shall seek to design switches and crossings away from structural piers and tunnel portals.

The project shall incorporate suitable measures to bar vehicular incursion on to the track from adjacent / overhead structures.

The project shall incorporate suitable security measures to prevent as far as reasonably practicable, the risk of trespass or vehicle intrusion.

The project shall determine the level of provision and nature of secure access points for maintenance.

4.4 Control-command and signalling requirements

Class A unified command-control interfaces shall be used.
The project shall assume a minimum of Level 2 ERTMS / ETCS for the Day One service.
The project shall assume that bi-directional signalling is required throughout the length of the route.
The project shall assume provision of one main control-command centre for the HS2 route. Appropriate fallback provisions shall be determined by the project.
The project shall assess the additional functionality required to enable the ultimate line capacity to be achieved in the longer term.
Telecommunication requirements shall be GSM-R or as further developed and required by TSIs at the time of opening the line.

4.5 Electrification and power

The project shall assume the provision of 25-0-25kV AC autotransformer fed overhead line equipment capable of supporting a minimum of 20tph in each direction
The contact wire height will be constant as defined in the TSI.
The AC energy supply shall be designed to permit the use of regenerative braking as a service brake able to exchange power seamlessly with other trains or with the primary network supplier.
The project shall confirm the high-level feasibility of National Grid supplies to any new high-speed line.

Provision shall be made for fixed lighting at junctions, tunnels and viaducts. Power supplies for the operation of portable maintenance equipment shall be provided along the route and at high value components.

4.6 Stations

The useful length of the platforms shall be at least 415m.

The project shall identify where longer platform lengths are required for operational purposes.

The height of platforms shall be 760mm.

The project shall assume a minimum platform width of 10m for the majority of the platform length to aid calculation of station footprints.

Platforms shall be straight to facilitate splitting and joining of trains.

HS2 stations shall be designed and built in accordance with the TSI for persons of reduced mobility.

The project shall consider providing station facilities to segregate international passenger flows.

The project shall identify additional railway infrastructure required to enable levels of connectivity required by the HS2 business case.

The project shall document assumptions made regarding the provision of station facilities such as train servicing, ticketing, lifts, concourse and retail areas to inform the calculation of each HS2 station footprint.

Specific evacuation requirements for stations (including underground stations) shall be determined during the development phase

The project shall provide an interchange between HS2, the Great Western Main Line and Crossrail with convenient access to Heathrow.

The project shall evaluate options for an intermediate parkway station between London and the West Midlands.

4.7 Level crossings (road and footpath)

Level crossings shall not be proposed for any part of the high speed route.

4.8 Other facilities

The project shall meet the following requirements for actual or passive provision of new facilities:

- one main rolling stock depot delivering light and heavy maintenance for the high speed rolling stock within 10 minutes journey time of the HS2 route; and
- additional rolling stock stabling facilities as required including provision at the London end.

The project shall meet the following requirements for actual or passive provision of new facilities:

- one main infrastructure maintenance depot mid-route; and
- additional maintenance depot / stabling facilities as required.

The project shall meet the following requirements for actual or passive provision of new facilities:

- one main control-command centre for the HS2 route and appropriate fallback facilities.

4.9 Interfaces with the existing rail network

The project shall demonstrate the feasibility of connection with HS1

The project shall identify any other proposed connections with the existing rail network and any infrastructure required to enable this interface.

5 Performance requirements

5.1 Passenger service performance

Passenger service performance and service reliability shall be consistent with current, world wide, high speed line practices with a maximum delay per train no greater than 30 seconds on any section.

5.2 Asset reliability and maintainability

A full life cycle preventative approach to design, installation and maintenance shall be applied to eliminate operational failure.

A route Failure Modes, Effects and Criticality Analysis (FMECA) shall be undertaken throughout all stages of the design, development and implementation to identify high risk or high value locations and to eliminate or mitigate the probability and severity of failure modes.

Infrastructure design shall optimise reliability, reduce the need for maintenance inspections, facilitate remote monitoring where possible and enable easy access for maintenance.

An asset database shall be developed through design and construction based around a geodetic control grid to locate and identify all asset components.

The monitoring and maintenance of fixed assets shall be undertaken without disruption to the operational railway.

High speed infrastructure recording and monitoring shall be undertaken in conjunction with the use of remote condition monitoring. Visual inspection shall be restricted to key assets and undertaken only when trains are not running.

Infrastructure condition degradation shall be detected through routine inspection and monitoring and rectified before causing infrastructure failure.

Achievement of the specified system punctuality / reliability will require infrastructure assets and configurations having high levels of Reliability and Maintainability (R&M). The specific numerical requirements are to be determined.

6 Sustainable design

6.1 Design principles

The project shall, through the design process, seek to avoid potential adverse impacts through the application of the sustainable design guidance.

6.2 Managing energy

The project shall consider the energy efficiency of the operation of trains and rail infrastructure (commensurate with the detail of design), as well as the energy requirements of construction and materials, as a means of establishing low energy priorities within the scheme as a whole.

6.3 Managing flood risk

The project shall aim to ensure no increase in flood risk. This will be achieved by maintaining overall flood storage capacity (through, in order of priority, option selection that avoids flood plains, infrastructure design and flood compensation) and avoiding disruption of flood flows.

6.4 Protecting environmental resources

The project shall seek to avoid direct or indirect harm to landscape, water and ecological resources, to mitigate adverse impacts where necessary, and to enhance such resources where practicable. Measures to achieve this will be commensurate with the sensitivity of the resource and will reflect the level of protection afforded such resources through relevant laws and policies.

The project shall assume that the route is for the use of electric trains with non polluting cargos. Diesel haulage shall be limited to engineering trains and recovery locomotives.

6.5 Protecting historic cultural resources

The project shall seek to avoid direct or indirect harm to historic cultural resources, to mitigate adverse impacts where necessary, and to enhance such resources where practicable. Measures to achieve this will be commensurate with the sensitivity of the resource and will reflect the level of protection afforded such resources through relevant laws and policies.

6.6 Controlling noise and vibration

Where reasonably practicable, the operation of HS2 infrastructure shall result in no significant adverse noise and vibration impacts (by reference to relevant guidance and precedence) to residents and other sensitive receptors near the route or proposed stations. Measures to mitigate potential impacts will be introduced, but where such impacts are unavoidable and cannot be appropriately mitigated, the project shall define circumstances under which residential properties shall be eligible for sound insulation.

Noise and vibration impact shall be assessed and mitigated through design and protection on the basis of a passenger only railway for the planned operational hours with maintenance and engineering activities outside of those times.

6.7 Minimising property impacts

The project shall seek to avoid or, where this is not practicable, to minimise demolition of properties and, in particular, to minimise residential land-take and demolition.

6.8 Protecting communities

The project shall seek to maintain the health and amenity of residential communities potentially affected by the scheme. This shall include, where practicable, maintenance of access to shops and services and maintenance of environmental conditions such that significant adverse effects on health and amenity are mitigated.

6.9 Optimising the land resource

The project shall seek, where practicable, to use land with planning designation appropriate to development for high speed rail and its infrastructure. The project shall seek to maintain and enhance land use, so long as this does not compromise other sustainability design aims.