High Speed Two (HS2) Limited
Rolling Stock & Depots (RS&D) Programme

Recommendation Paper

Subject:	Technical Specification Parameters Part 2: Design Life, Operations, Noise and Vibration.
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1. Purpose

1.1. The purpose of this paper is to seek endorsement for HS2's recommendations on the approach to specification of the Phase One Rolling Stock with respect to design life, operations and noise and vibration. This is one of a number of papers presenting recommendations related to the train specification, as further detailed in the introduction below.

1.2. Endorsement of these recommendations will enable completion of the technical documents which will accompany the Phase One Rolling Stock Pre-Qualification Questionnaire (PQQ).

2. Introduction

2.1. The Phase One Rolling Stock Contract Notice is due to be published in April 2017. The Pre-Qualification Pack provided with the Contract Notice will include the Pre-Qualification Technical Summary (PQTS) which will set out the material high-level requirements of the technical specification for the Phase One Rolling Stock. Requirements have been designated as material if they are considered to influence suppliers in their decision on whether or not they will seek to enter the competition. The PQTS is a precursor to the full Train Technical Specification (TTS), which will be provided with the Invitation to Tender in early 2018.

2.2. The basis for designating a requirement as material at the time of the Contract Notice is as follows:

- The market is 'split' by the requirement in terms of the ability of certain suppliers to meet that requirement (and therefore ability to respond); or
- Where an unproven or particular challenging system solution will be required (therefore providing early sight of the requirement at Contract Notice allows manufacturers additional time to develop solutions).

Where a requirement is subject to further change as a result of an as yet unmade decision or unstable principal requirement, appropriate wording will be included in the PQTS to mitigate the risk of procurement challenge in case the requirement does change between the PQTS and the TTS.

2.3. This board paper makes recommendations on the approach to be taken on key elements of the Rolling Stock specification where there is expected to be particular interest from key stakeholders. Whilst stakeholders will have the opportunity to review the final PQTS (and later the TTS), reviewing the approach at this earlier stage is intended to assist de-risking of the development process.

2.4. To support these recommendations, this paper summarises how the approach aligns with the RS&D Programme Objectives & Success Criteria, Development Agreement (Sponsors Requirements and Functional Response) and Business Case assumptions. A summary of the assurance underpinning the recommendations is also provided.

2.5. Recommendations on a number of other areas of the specification are being presented through dedicated papers due to the complexity of the justification and evidence supporting them. Recommendations on the remaining areas are being presented in two parts with this paper containing the second part.

2.6. Table 1 provides the complete list of specification areas on which we are seeking endorsement for our recommendations, along with a reference to the technical paper in which each is addressed.

Table 1 – Technical Specification Topic Areas

Specification Topic	Paper
Train length and train configuration strategy in case of platform edge protection system adoption	Within Fleet Solution paper (HS2-HS2-RR-PPR-000-000010)
Speed and performance parameters to meet Journey Time requirements	Dedicated Board paper - HS2-HS2-RR-PPR-000-000006
Train and Platform Interaction	Dedicated Board paper - HS2-HS2-RR-PPR-000-000007
Management of Operator requirements (including interior design and flexibility strategy)	Dedicated Board paper - HS2-HS2-RR-PPR-000-000009
Specification Approach to industry standards	Technical Specification Parameters paper part 1 (and further detailed in Supporting Technical paper: HS2-HS2-RR-PPR-000-000014)
Approach to Noise and Vibration	**This paper (and further detailed in Supporting Technical paper: HS2-HS2-RR-PPR-000-000015)**
Approach to Design Life	**This paper (and further detailed in Supporting Technical paper: HS2-HS2-RR-PPR-000-000016)**
Classic Network Compatibility Approach	Technical Specification Parameters paper part 1 (and further detailed in Supporting Technical paper: HS2-HS2-RR-PPR-000-000017)
Approach to Operational Flexibility, Interworking and Recovery	Technical Specification Parameters paper part 1 (and further detailed in Supporting Technical paper: HS2-HS2-RR-PPR-000-000018)
Approach to train control and automation	**This paper (and further detailed in Supporting Technical paper: HS2-HS2-RR-PPR-000-000019)**

Specification Topic	Paper
Rolling Stock Interface with Infrastructure Maintenance	Technical Specification Parameters paper part 1 (and further detailed in Supporting Technical paper: HS2-HS2-RR-PPR-000-000020)
Rolling Stock Reliability Requirements	Technical Specification Parameters paper part 1 (and further detailed in Supporting Technical paper: HS2-HS2-RR-PPR-000-000021)
Rolling Stock Approach to Vehicle Track Interaction	Technical Specification Parameters paper part 1 (and further detailed in Supporting Technical paper: HS2-HS2-RR-PPR-000-000022)

2.7. The rest of this document consists of the following sections:

- The recommendations, justification, other options considered and rationale for selection or rejection are described in sections 3 to 5;
- Addressing the RS&D Objectives & Success Criteria including consideration of the Development Agreement, Options, Business Case is included in Section 6;
- The assurance undertaken for this technical board paper is set-out in Section 7.

3. Specification Approach to Design Life

Why this is material and needs to be included in the PQTS

3.1. The Design Life of the train is a key determining factor of the HS2 Business Case as it establishes the number of procurement cycles required within the life of the railway and it provides an equal basis for undertaking a Whole Life Cost evaluation in the procurement competition, which reduces risk of challenge from unfair appraisal of tenders.

3.2. Design Life is also considered material to Rolling Stock manufacturers as it defines the fatigue loading design cases for key systems within the train, e.g. the carbody, as well as defining key elements of the Rolling Stock manufacturer's ongoing risk profile following the end of the general train warranty.

Recommendations

Recommendation 7a:
HS2 recommends that a Design Life of 35-years be specified for the HS2 Phase 1 Rolling Stock.

Justification

3.3. A 35-year Design Life specification is consistent with other recent UK Rolling Stock procurements including Thameslink, Crossrail, Edinburgh Glasgow Improvement Programme and New Tube for London (40 years). A 35-year Design Life was also specified for Siemens Velaro High Speed Trains for Eurostar. It is also broadly consistent with the requirements of the recent Renfe VHS procurement (30 years) and the service lives of operating VHS trains in Europe. A review has been undertaken with the aim of benchmarking the Design Life of other VHSTs, which has identified that whilst examples exist of fleet replacement around 20 years; these have largely been due to delivering required improvements in performance.

3.4. HS2 issued initial market sounding questionnaires to potential suppliers in March 2015. This elicited responses from potential suppliers concerning two OTTR requirements: OTTR-1035 (Design Life) and OTTR-436 (Fatigue Cycles). Responses identified that a number of suppliers had initial concerns regarding the 35 year design life coupled with the assumed fatigue loads, as this appeared to exceed the cyclic loading capacity of their current high speed vehicle designs. The Design Life specification was therefore explored in more detail when HS2 issued Market Sounding Briefing & Questionnaires in November 2015.

3.5. Having considered the specifications further, suppliers confirmed that the 35-year design life would be deliverable. Half of the suppliers indicated their current carbodies would achieve this. The others indicated that some further analysis and maybe some structural reinforcement of existing bodyshell design might be required, but this was considered feasible.

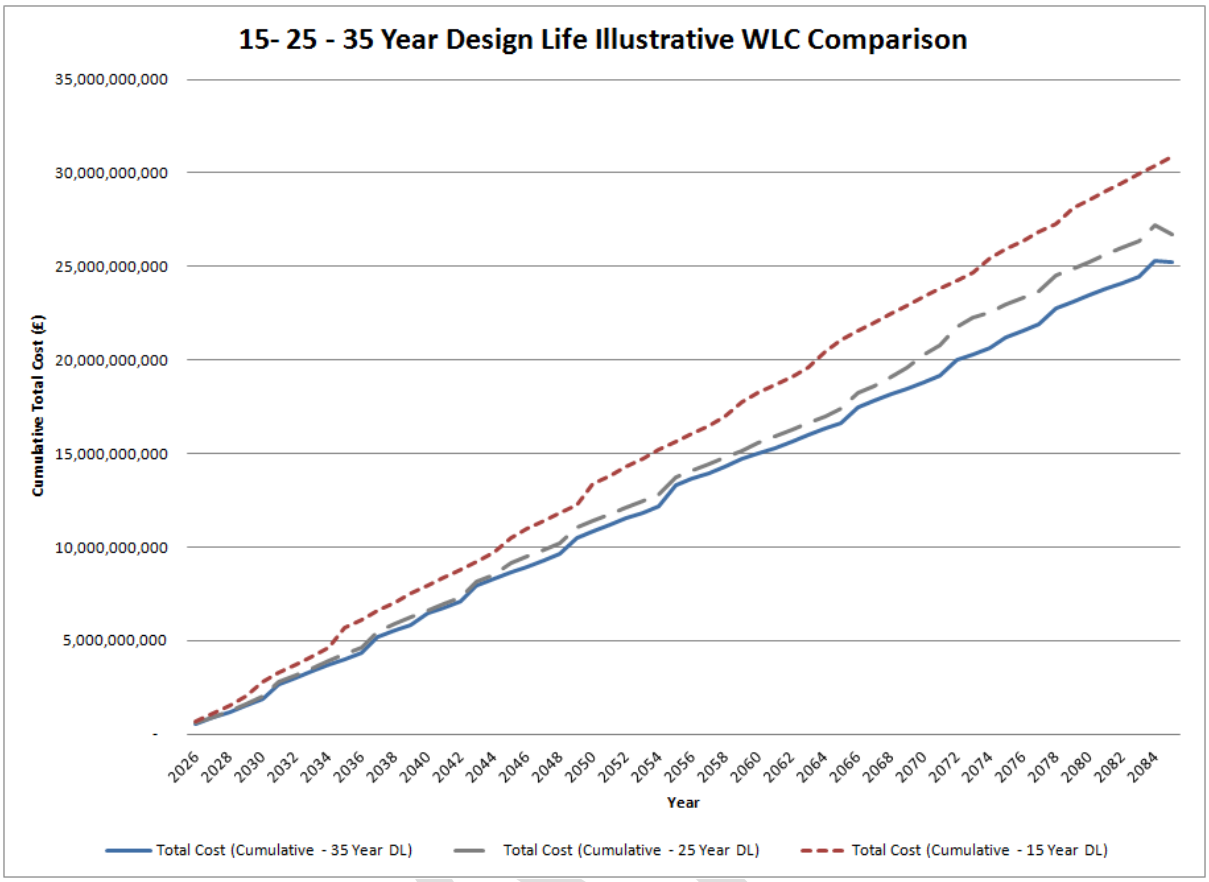
3.6. The Commercial Principles paper supporting the HS2 Economic Case assumes the manufacturer will provide a general three year warranty period under the MSA and a design life warranty for each Train of 35 years; including appropriate extended warranties for key components (up to 35 years).

3.7. HS2's analysis and benchmarking has not identified sufficient technical justification to deviate from these business case assumptions and Commercial Principles.

3.8. HS2 has considered whether Rolling Stock with shorter design life potentially delivers lower whole life costs. 25-year and 15-year design life variants have been compared to a baseline 35-year whole life cost model. Analysis compared the potential costs and benefits of HS2 Phase 1 Rolling Stock procurement cycles over a 60-year period to be consistent with the Economic Case and consistent input data has been used as far as practicable

3.9. The whole life cost profiles in the following graphs show there is minimal difference in whole life cost between 35-year and 25-year design, given the level of accuracy to be expected from the calculations. The increased procurement cost in the 25-year design model is offset by reduced refurbishment cost, cost efficiencies, commercial risk, and finance rates. The 15-year design has significantly higher whole life costs due to procurement/capital costs outweighing potential efficiency savings and refurbishment costs.

3.10. The whole life cost comparison is close enough to not discount specifying a shorter design life if considered advantageous in some other way by HS2, however based on this assessment of potential whole life cost alone, there is no clear justification to change the Design Life requirements.



3.11. Other option(s) that were considered:

Option	Reason for rejection
25 year design life	Design life specification for less than 30 years will require additional procurement cycles. Whilst this brings forward opportunities to replace Rolling Stock with more efficient and better performing technologies, it also increases commercial risk related to long-term cost of Rolling Stock. Whole Life Cost analysis of 25-year design life variants have not demonstrated significant difference in total costs over the Appraisal Period compared to existing 35-year assumptions.
15 year design life	A 15-year design life would require double the current assumed number of procurement cycles. Examples of short-term Rolling Stock replacement in other operations have been justified by delivering changes in performance after the point of introduction, which deliver specific benefit or improvement. There is no clear evidence that short-term replacement as a procurement strategy would lead to lower whole life costs. Whole Life Cost analysis of 15-year design life variants estimated a significant increase in total costs over the Appraisal Period compared to existing 35-year assumptions.
Unspecified Design Life	If left undefined, or for the manufacturers to define, manufacturers may be inclined to propose very short Design Life with high-risk transfer to HS2 and the operator. Submissions for different products with variations in design life would make financial evaluation difficult and open to risk of challenge. Design Life and associated warranties underpin HS2's Commercial Principles.

	Definition of a Design Life provides a contractual requirement in the MSA against which the manufacture can demonstrate compliance.

3.12. Note: A 30-year design life was not considered as procurement for the third Rolling Stock procurement would need to start before the end of the 60-year appraisal was reached.

> *Recommendation: 7b*
> *HS2 recommends at this time that the Design Life requirement is a scored and not a mandatory criterion in the evaluation process.*

Justification

3.13. Bid Evaluation will consider Design Life as a Scored Requirement. This is partly because there is an argument that full demonstration of this requirement at bid stage is not possible.

3.14. A scored requirement would require a degree of compliance (rather than full compliance to a Mandatory Requirement), which allows a degree of concession in compliance against the requirement subject to a sound and transparent justification in the evaluation.

3.15. Analysis undertaken does not suggest there is a significant advantage in specifying a longer or shorter than 35-year design life, however it also does not suggest that there is a significant disadvantage in an alternative design life. Individual manufacturers may be able to propose benefits in the design (e.g. decreased mass) as a result of a shorter design life but this would be treated as a clear transfer of risk to HS2 which would need to be assessed accordingly.

3.16. It provides HS2 flexibility to accommodate some deviation to Design Life subject to the manufacturer being able to demonstrate sound technical justification for partial-compliance as well as sound justification for lower Whole Life Cost of the business case appraisal period being attainable.

3.17. Manufacturers may propose an alternative Design Life subject to a technical and commercial justification and subject to HS2 satisfying itself that fair and transparent evaluation of bids is possible.

3.18. The evaluation methodology will need to be developed to accommodate such a deviation. Legal/procurement advice will be required to develop this methodology. The change in commercial risk profile associated with additional procurement cycles will need to be assessed to ensure that bids are being evaluated fairly and transparently.

3.19. Other option(s) that were considered:

Option	Reason for rejection
Design Life specification classed as a mandatory requirement	There is a risk of HS2 being perceived to preclude bidders at an early stage. Recommendation 2 therefore allows justifiable concession against the Design Life specification. Mandatory, Pass/Fail, requirements require clear demonstration of compliance to ensure requirements are not open to challenge. This is difficult to demonstrate in the case of design life. Mandatory requirement specification restricts HS2's ability to accept deviation or risk to delivery of this requirement subject to sound technical or commercial justification.

4. Approach to train control and automation

Why this is material and needs to be included in the PQTS

4.1. There are a number of areas where Rolling Stock features will need to be provided to support the Operational Concept. These features have been assessed to be material to the Rolling Stock scope (either individually or in combination) such that we will need to include them in the technical specification to be provided in the PQTS. There is also the potential for requiring manufacturers to support novel and/or technically complex solutions to deliver optimised operation of the railway, as such it is considered prudent to provide prior warning of these areas even where a final decision has not yet been taken as to the solution to be adopted for HS2. An operational functions options analysis is therefore being undertaken to allow selection of operational solutions such that the Rolling Stock can be appropriately specified.

Recommendations

Recommendation 8a: Grade of Automation

Phase 1 trains should be specified to operate on HS2 infrastructure at Grade of Automation 2 (GoA 2) using ATO over ETCS with the capability to operate at all ETCS levels, but in Level 2 or 3 only when operating in GoA2 .

Justification

4.2. The level to which the operation of the Trains is automated has wide reaching implications for the wider operational concept and the railway and Rolling Stock design. The level of driving automation of a railway is known at the Grade of Automation (GoA). On the Conventional Rail Network (CRN), Trains will need to be driven manually with a driver in the cab. This is referred to as GoA1.

4.3. The HS2 scheme ultimately requires an 18 trains per hour (tph) capability with high punctuality and precision. This can best be ensured through adoption of Automatic Train Operation (ATO). ATO supports the minimisation of energy consumption, which offers significant operational cost and carbon savings. If platform edge doors are adopted (a decision which will be made prior to ITT), high precision in stopping accuracy will be essential and this cannot be reliably achieved with manual driving.

4.4. HS2-HS2-RR-PPR-000-000013 outlines the investigation in to potential options for automation both in terms of the GoA level to be adopted and the method for delivering that automation. The report concludes that there are significant operational advantages to the use of ATO and that the resilience of the railway will be significantly improved along with supporting the ultimate goal of delivering 18tph.

4.5. The use of an ETCS based solution provides the opportunity to use a standard interoperable solution which will allow HS2 to procure future signalling equipment and maintenance from a wider range of suppliers whilst mitigating the risk related to obsolescence due to the large installed base of ETCS systems worldwide.

4.6. The proposed text for the PQTS is as follows:

The current assumption is that in normal operation, HS2 Trains will operate under ATO (GoA2) while on the HS2 network and that ATO data will be provided over ETCS and the operational radio system. ATO will only be possible in ETCS full supervision mode. It is currently proposed

that the Rolling Stock manufacturer would be responsible for delivering the on-board equipment. This will require the chosen supplier to work closely with HS2 and our trackside CCS supplier and to integrate systems which will together provide the required railway functionality.

On the CRN, the Unit will be operated in manual driving mode.

The Unit shall be able to operate at the following ERTMS application levels:

- *Level 0;*
- *Level NTC;*
- *Level 1;*
- *Level 2; and*
- *Level 3.*

On the CRN, the Unit shall operate with protection from the existing AWS and TPWS systems. (These systems may be upgraded to ETCS within the life of the Unit.)

The Unit shall be able to transition from the signalling system on the HS2 network and the system on the CRN in service at any speed up to line speed. Throughout each transition the Unit shall remain protected by at least one of the train protection systems.

4.7. Other option(s) that were considered:

Option	Reason for rejection
Use of GoA1 operation on HS2	Challenges related to consistency and accuracy of driving style leading to potential delays, poor stopping accuracy and increased energy consumption.
Use of GoA3/4 operation on HS2 to allow trains to be driven without a member of staff present in the cab	Not currently supported by standards roadmap for ETCS. No possibility to remove the cab and therefore gain additional space for passengers due to operation on CRN. GoA2 operation of Phase 1 trains does not preclude fleets procured for Phase 2 to be specified with higher Grades of Automation such that they can run in traffic with the Phase 1 fleet.
Use of a bespoke, metro-type CBTC signalling system	Conflict with legal requirement to adopt Technical Specifications for Interoperability (TSIs). No solution available suitable for high speed operation leading to need to develop bespoke solution and therefore presenting commercial and obsolescence challenges associated with single source of supply.

Recommendation 8b: Provision for Higher Grades of Automation

Phase 1 trains should not be required to include specific provision for higher grades of automation.

Justification

4.8. It is not currently possible to describe or develop requirements for any provision to migrate to higher grades of automation due to the lack of maturity in the development of an

interoperable solution for ATO over ETCS with GoA3 or 4[1], particularly for the operation of high speed trains[2]. It is currently not considered likely that this solution will be sufficiently developed to support the timescales for Phase 1 Rolling Stock procurement.

4.9. In addition to the development of an interoperable solution for driverless operation, or in a scenario where HS2 was to develop a non-interoperable solution, there would be a need to significantly accelerate the development of the HS2 operational concept in order to understand the functionality required from a GoA3 or 4 railway.

4.10. There is a significant challenge with the development of options or provision for changes to Rolling Stock that cannot be described, even if they can be theoretically foreseen. Given the lack of clarity available to define this provision, it is likely that the scope and cost of this variation would be similar to one to add functionality to a train without any provision and as such would not deliver Value for Money to HS2.

4.11. It should be noted that the inclusion of functionality to only support GoA2 in the Phase 1 Rolling Stock would not preclude Phase 2 Rolling Stock being specified to support GoA3 or 4 as the ETCS and ATO functionality would allow the trains to operate in traffic together.

4.12. Other option(s) that were considered:

Option	Reason for rejection
Include provision for GoA3 or 4 in Phase 1 Rolling Stock	It is not currently possible to define the provision that manufacturers would need to provide. This issue is not expected to change before the release of the ITT.

Recommendation 8c: Standalone Depot Automation

Phase 1 Rolling Stock should not provision to have a standalone system to provide automated, driverless moves within the depot alone. However, trains should be specified to allow reversing moves without requiring the driver to have to change ends.

Justification

4.13. HS2-HS2-RR-PPR-000-000012 includes a high-level financial appraisal of the potential benefits of allowing driverless moves (including reversing) within the depot confines. This led to a potential saving of approximately £3m over the 35 year anticipated design life of the trains. The paper includes an estimated cost of delivering these benefits of £32m and as such, there is not considered to be a net benefit of delivering this functionality.

4.14. The potential savings that could be gained by allowing trains to reverse without the driver needing to change ends was valued at approximately £1.8m over 35 years. This includes the cost of delivering the additional functionality, which is considered relatively low at approximately £1500 per Unit, which reflects the fact that this is a far more simple technical solution.

[1] GoA 3 refers to operation of trains without a member of staff in the cab but with staff present on trains to be responsible for key operations such as door control. GoA4 refers to fully automated, driverless operation of trains, which is not reliant on any member of staff on the train.

[2] HS2 is likely to be the first Very High Speed railway in the world to specify GoA2, let alone a higher grade of Automation.

4.15. As such, the option for reversing trains is considered to deliver a net benefit whereas the option for standalone automation within the depot environment is not considered to deliver Value for Money to HS2.

4.16. Other option(s) that were considered:

Option	Reason for rejection
Standalone driverless control system for depot only	Not able to deliver savings to warrant technical risk related to development.

Recommendation 8d: Driverless ECS Moves to/from depot

Phase 1 Rolling Stock should not have provision for a standalone system to provide automated, driverless moves between the depot and the first/last station on HS2 infrastructure.

Justification

4.17. HS2-HS2-RR-PPR-000-000012 includes a high-level financial appraisal of the potential benefits of delivering driverless moves from Washwood Heath depot to Birmingham Curzon Street and Birmingham Interchange stations. This led to a potential saving of approximately £51.3m over 35 years. This is weighed up against a cost of approximately £49m.

4.18. Especially given that the costs included are felt to be incomplete, the difference in these savings was not considered substantial enough to warrant the technical risk and complexity associated with the development of a bespoke control system for the depots.

4.19. Other option(s) that were considered:

Option	Reason for rejection
Standalone driverless control system for ECS moves from depot to Birmingham Stations	Not able to deliver significant savings to warrant technical risk related to development.

Recommendation 8e: Train Dispatch

A decision on the method of Train dispatch to be used should be made later, prior to ITT, to allow other related decisions to be made and for further cost benefit analysis to take place. A list of potential options will be included in the PQTS to inform the market of options that may need to be supported by the Rolling Stock.

Justification

4.20. The method for delivering safe dispatch of trains from platforms has significant implications for the wider operational concept and the railway and Rolling Stock design. The solution or combination of solutions could be material to the Rolling Stock solution if there is significant novelty in the approach, or the solution could mandate that specific equipment is positioned on the infrastructure or that specific staffing is required on platforms.

4.21. A sift process has been carried out, which is described in HS2-HS2-RR-PPR-000-000013, to evaluate the full range of possible Train Dispatch options, considering both systems of work in place on the mainline railway today and system requiring technological or operational innovation.

4.22. This analysis leads to 10 potential solutions which require further analysis to understand the operational benefits and also the impact of other decisions, such as whether or not Platform Edge Protection is to be fitted to HS2 infrastructure. At present, the following options have been retained for further consideration:

- Train dispatch by Train Captain/Driver and Platform Staff, using CD/RA indicators;
- Train dispatch by Train Guard and Platform Staff, using CD/RA indicators;
- Train dispatch by Train Captain/Driver and Platform Staff;
- Train dispatch by Train Guard and Platform Staff;
- DOO train dispatch with train mounted cameras;
- DOO train dispatch with platform mounted cameras;
- Two person, On-Board Staff dispatch for 400m train using train mounted cameras (1 in each 200m Unit);
- Two person, On-Board Staff dispatch for 400m train using platform mounted cameras (1 in each 200m Unit);
- Automatic train dispatch with train-borne obstacle and dispatch corridor intrusion detection using train-borne cameras; and
- Automatic train dispatch with infrastructure mounted track and dispatch corridor intrusion detection systems.

4.23. These solutions lead to 6 High Level options for Rolling Stock which would have the following impacts:

High-Level Rolling Stock Option	**Impact on Rolling Stock**
Platform Staff Dispatch in communication with the Train Captain/Driver	Visibility required for driver of platform staff and or platform indicators
Platform Staff Dispatch in communication with the Train Guard	Train Guard door controls required to be distributed along train. DGO functions to be included in door control
DOO or Two person dispatch using train-borne cameras	Train mounted cameras to be included on a per car or per doorway basis. Resolution of safety case for long trains (number of images)
DOO or Two person dispatch using platform mounted cameras	Communications equipment and interfaces for transmission of platform cameras to the train. (Responsibility for definition of this system to be defined) Resolution of safety case for long trains (number of images)
Automatic Dispatch with train-borne obstacle detection and PTI intrusion detection	Development of obstacle detection for way ahead (current systems based on impact would not be acceptable) Development of system to scan PTI around doorways
Automatic Dispatch with infrastructure mounted obstacle detection and PTI intrusion detection	None

4.24. As such, the PQTS will include a guidance note to explain to manufacturers that they could need to support one or a combination of the solutions listed being incorporated on to the Phase 1 Units.

4.25. The proposed text for the PQTS is as follows:

HS2 is still determining how train dispatch will be achieved and the method of dispatch selected is likely to be significantly affected by decision on whether to fit a PED system. Options under consideration include:

- *Dispatch by Platform Staff in communication with a Train Captain/Driver;*
- *Dispatch by Platform Staff in communication with a Train Guard;*
- *Dispatch by one or two members (in different cabs) of on train staff using images from train-borne cameras;*
- *Dispatch by one or two members (in different cabs) of on train staff using images from platform mounted cameras;*
- *Automatic dispatch using train-borne detection of obstacles on the route ahead and obstacles in the Platform Train Interface; and*
- *Automatic dispatch using infrastructure mounted detection of obstacles on the route ahead and obstacles in the Platform Train Interface.*

The performance requirements for Train dispatch, along with the scope split for the Rolling Stock manufacturer, will be detailed in the Rolling Stock ITT. It is possible that Rolling Stock will be required to support more than one of the options listed above.

4.26. Other option(s) that were considered:

Option	Reason for rejection
Train dispatch with Train Captain/Driver, on-board staff and platform mirrors	Discounted due to the unsuitability of the use of platform mirrors on the Train lengths proposed for HS2
Automatic train dispatch with train-borne or trackside obstacle detection without dispatch corridor intrusion detection	Discounted, as it is not considered viable from a safety point of view to have Automatic Dispatch of trains without the ability to verify that no intrusions are present in the Platform Train Interface (PTI). This would lead to an unmitigated risk that Trains could be dispatched with passengers trapped between the train and PED system.

Recommendation 8f: Automated Splitting and Joining

A decision on the method of delivering splitting and joining to be used should be made later, prior to ITT, to allow further cost benefit analysis to take place. A list of potential options will be included in the PQTS to inform the market of options that may need to be supported by the Rolling Stock.

Justification

4.27. The method for delivering automated coupling and uncoupling of trains has significant implications for the wider operational concept and the railway and Rolling Stock design. The solution or combination of solutions could be considered material to the Rolling Stock

solution if there is significant novelty in the approach or additionally, the solution could mandate that specific additional systems are added to the train to deliver safe operation during a coupling procedure.

4.28. A sift process has been carried out, which is described in HS2-HS2-RR-PPR-000-000027, to evaluate the full range of possible options for delivering coupling, this work has assumed that the HS2 railway includes GoA2 operation and as such when considering systems of work in place on the mainline railway today these have been adjusted.

4.29. This analysis leads to 10 potential solutions which require further analysis to understand the operational benefits and also the impact of other decisions, such as whether or not Platform Edge Protection is to be fitted to HS2 infrastructure. At present, the following options have been retained for further consideration:

- ATO and traditional approach (2 stops) - ATO drives train to 40m from stationary unit using maximum brake rate. Train Operator takes over and drives to 2m, stops, then drives forward to couple
- ATO with virtual blocks, no stop - ATO drives the train towards the end of the last free virtual block (beyond end of physical block to allow trains movement authority to draw closer together). Train Operator takes control when speed is around 5 km/h and presses "couple shunt" button which brings speed to 2 km/h. Button held until couple complete
- ATO then approach control button, no stops - ATO drives train towards 40m stopping position; Train Operator disengages ATO once speed is at circa 30km/h and presses "approach control" button, which brings speed down to 2km/h for final 5m until the point of coupling using proximity detection of the stationary unit. Button held until couple complete.

These solutions lead to the following impacts on Rolling Stock:

High-Level Rolling Stock Option	Impact on Rolling Stock
ATO and traditional approach (2 stops)	No additional development
ATO with virtual blocks, no stop	Requires on-board signalling equipment to support the use of virtual blocks
ATO then approach control button, no stops	Requires development of additional distance measurement system to provide ATP beyond the ETCS movement authority. Could be in the form of Radar and or camera based systems

4.30. As such, the PQTS will include a guidance note to explain to manufacturers that they could need to support one or a combination of the solutions listed being incorporated on to the Phase 1 Units.

4.31. The proposed text for the PQTS is as follows:

Coupling and uncoupling operations shall be automated and shall not impose restrictions on other operational aspects, such as train doors being closed on a static Unit.

HS2 is currently investigating options for providing increased automation of the coupling procedure when compared to current UK mainline practice with the aim of eliminating the need for intermediate stops.

These options include:

- *The use of virtual blocks to allow the Train to draw up close to the Unit to be coupled to under ATO control before allowing a member of staff in the cab to use a shunt control to complete the coupling manoeuvre.*
- *The use of an automated distance measurement system to provide automatic speed control in the area between the end of the ETCS movement authority and the Unit to be coupled.*

In both of these cases, the Units would need to automatically prepare for a coupling operation.

4.32. Other option(s) that were considered:

Option	Reason for rejection
ATO then manual approach, one stop	Discounted due to only providing a minimal saving in terms of time whilst requiring an increase in the skill level of the Train Captain/Driver due to the need to take over manual operation of the train in a consistent way whilst observing the way ahead and the coupling operation. Additionally, given the speed at which the Train Captain/Driver is likely to take over control of the Train there is an increased risk of ETCS intervention.
ATO then couple shunt button, no stops	Discounted due to the significant increase in time taken to complete the coupling operation compared to the base case.

5. Approach to Noise and Vibration

Background

5.1. Noise and vibration produced by the HS2 railway is a key issue, both in terms of minimising environmental impact arising operation of the new railway and in meeting the aspiration to provide a world-class passenger experience.

5.2. As part of the Hybrid Bill process an Environmental Impact Assessment (EIA) was undertaken and the resulting Environmental Statement (ES) deposited with the Bill in 2013. Additional Provisions (APs) have required the preparation and deposit of supplementary ESs during the House of Commons Select Committee process. The ESs included an assessment of the predicted noise and vibration impacts of the operating HS2 Phase 1 in the Phase 2B end state operation, i.e. 18 trains per hour. Analysis was based on a whole system approach with rolling stock being a key contributor.

5.3. The sources of rolling stock pass-by noise are:

- Traction and auxiliary equipment noise;
- Wheel-rail rolling noise; and
- Aerodynamic noise from vehicle bodies, bogies, pantographs and pantograph recesses.

5.4. The dominant noise sources for focus at high speed are wheel-rail rolling noise and aerodynamic noise from vehicle bodies and pantographs. Due to their high elevation above the track, pantograph noise can lead to infrastructure based sound barriers being of limited benefit. Traction and auxiliary equipment noise is not significant at high speed.

5.5. The predicted noise and vibration impacts were determined through modelling based upon 'real' rolling stock performance data from high speed railways already in operation elsewhere. The predicted noise considered the adoption of the best low noise technology in use at that time for rolling stock worldwide low noise pantographs and bogie fairings.

5.6. Noise modelling as part of the EIA assumed that HS2 trains will be specified to be quieter than the relevant current European Union requirements and this will include reduction of aerodynamic noise from the pantograph that would occur above 300kph (186mph) with current pantograph designs, drawing on proven technology in use in East Asia. It is also assumed that the track will be specified to reduce noise, as will the maintenance regime. As a result, it was assumed that the rolling stock pass-by external noise emissions to be 92 dB(A) $L_{pAeq,Tp}$ at 360 km/h. This is 4 dB(A) lower than the rolling stock Noise TSI[3] limits extrapolated from 320 km/ to 360 km/h and based upon a test position of 25m (rather than 7.5m). To put this into perspective, a 4dB(A) reduction is significant and will require the sound energy level to be more than halved.

5.7. With rolling stock noise set at 92 dB(A) $L_{pAeq,Tp}$, around 14,000 residential properties would be adversely affected rather than 27,000 residential properties, which would be the case with the Noise TSI performance.

5.8. The HS2 scheme includes the provision of noise barriers along the Phase 1 route to mitigate some noise emissions from train operations. However, noise emissions at higher elevations

[3] COMMISSION REGULATION (EU) No 1304/2014

cannot be mitigated by noise barriers, and hence a specific target is required for noise emitted from the upper sections of the rolling stock.

5.9. The overarching environmental commitments of the scheme are set out in the Draft Environmental Minimum Requirements[4]. In summary, the Environmental Minimum Requirements (EMRs) require that no new significant adverse environmental effects will occur, beyond those reported in the Phase One ES and its supplementary ESs, unless they result from a change in circumstances which were not likely at the time of the ES or result from changes which require a separate EIA to be undertaken.

5.10. As part of the route-wide parliamentary assurances, Section 3 of Information Paper E20 sets out the objectives for the control of airborne noise from altered roads and the operational railway. This includes commitments to "take all reasonable steps" to design, construct and operate the railway so that the criteria in Tables 1 and 2 are not exceeded. Section 4 requires that noise reduction at source (from the train and track) will be considered before noise barriers and noise insulation and that the set of shared UK principles that underpin the Government's sustainable development strategy will be taken into account to ensure that the measures to control airborne noise are reasonable.

5.11. Recognising the exterior pass-by noise challenge and the environmental commitments, HS2 has completed a specific market sounding on the subject of noise with rolling stock suppliers. The key outcomes of this market sounding were:

- The overall pass-by noise requirement of 92 dB(A) $L_{pAeq,Tp}$ at 360km/h was deemed challenging. For a Captive (CP) train some developments are considered necessary but are feasible as most suppliers were able to point to areas of research and development that could provide improvements;
- Rolling Stock and pantograph suppliers were consulted and all raised concerns about the requirement for a specific pantograph noise value. All suggested the value prescribed was extremely challenging.
- Several manufacturers raised concerns that the noise performance of Conventional Compatible (CC) trains could be impaired by the design restrictions imposed by reduced gauge. The lower sector gauge may prevent the use of bogie fairings, which are commonly used to reduce the noise emissions from existing train designs. The low overhead line height in some locations and lack of height in the gauge could also make pantograph noise mitigations significantly more challenging. Any fairings to enable low noise pantographs on HS2 is likely to infringe the Conventional network gauge.

Why this is material and needs to be included in the PQTS

5.12. Given the recent rolling stock strategy recommendation to only procure CC trains for Phase 1, delivering noise performance below the Noise TSI is a very onerous requirement and could have a significant impact on manufacturers. Implementing existing noise-mitigation technologies, such as low noise pantographs and bogie fairings is more challenging on CC trains because of the gauge constraints.

[4]https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/509195/EMR_Draft_General_principles.pdf

5.13. Vibration requirements for rolling stock are not material to the rolling stock contract. These are normally resolved by the rolling stock suspension design with the track. These requirements will be finalised and detailed in the Train Technical Specification. The development process will include market sounding.

Recommendations

Recommendation 9a: Engage with suppliers to understand possible noise performance of conventional-compatible units.

In the PQTS, inform suppliers of the existing noise assumptions and the need to minimise noise as far as reasonably practicable at source.

State that the requirements will be confirmed in the ITT and that we will engage with them prior to ITT to ensure the requirements are achievable.

Request information from manufacturers to understand the likely performance of CC trains and the measures that could be adopted to mitigate noise

Justification

5.14. The majority of noise modelling and supplier-engagement to date has not specifically differentiated between CP and CC rolling stock. This is where focus is needed now. There is insufficient information currently available to be sure that CC rolling stock could meet the Noise TSI limits or HS2's aspiration for quieter rolling stock. Given the restrictions of the conventional rail network gauge, existing noise-mitigation measures may be impracticable, but manufacturers may be able to suggest alternative solutions.

5.15. Manufacturers will be provided with specific questions on noise performance with draft versions of the PQTS and TTS to elicit manufacturers' experience.

5.16. In addition, HS2 will engage in the wider supply chain to understand what technologies are available and their suitability to the CC rolling stock.

5.17. HS2 will collate information from manufacturers and the wider supply chain to form an opinion on what level of noise from CC rolling stock is *reasonably practicable*. This will include consideration of costs to the rolling stock, as well as costs to the wider railway.

5.18. **Other option(s) that were considered:**

Option	Reason for rejection
Providing a specific noise target in the PQTS	If a clear target was set in the PQTS, this would need to be retained in the TTS. There is insufficient information to support a specific target. With the current information, it could not be demonstrated that the target was as low as reasonably practicable.
Specifying that noise would be incentivised	Although not currently adopted, this option may be considered in future. It cannot be ensured that incentivsation will achieve a noise level as low as reasonably practicable. When combined with other elements of a tender evaluation model, noise emissions may get out-weighed and manufacturers may not consider noise improvements worth considering

Recommendation 9b: Review noise modelling

Review and revise the noise modelling assumptions of the acoustic performance of CP and CC trains; iterate this with feedback from suppliers

Justification

5.19. The noise modelling undertaken to date includes the original assumptions for the split of CP and CC rolling stock and included 'just' TSI compliant high speed rolling stock with origin/destinations via HS1.

5.20. The modelling needs to be updated to include the latest knowledge of the Train Service Specification and associated rolling stock deployment. Based on supplier feedback to questions in the draft PQTS and draft TTS, the modelling can be further updated to include more representative assumptions about the rolling stock. Through a process of iteration, it will be possible to better understand the noise levels that the CC rolling stock must meet to ensure the EMRs are not exceeded.

5.21. Note that this does not remove the requirement to pursue noise reductions where they are reasonably practicable.

5.22. **Other option(s) that were considered:**

Option	Reason for rejection
Do not undertake further modelling	The modelling was undertaken in 2013 based on the best available information at that time. A number of assumptions have changed that could be material

Recommendation 9c: Undertake gauging studies

Continue gauging analysis, supported by supplier feedback, to understand the available space for noise mitigation, specifically around the bogie and around the pantograph

Justification

5.23. The key limitation to applying existing noise-mitigation technologies used in current high speed train design to CC trains is the restricted gauge of the conventional rail network. HS2 Ltd is undertaking gauging studies to understand the impact of increasing the size of the CC rolling stock to allow better noise-mitigation (as well as other benefits).

5.24. This work may lead to key decisions that need to be agreed with all stakeholders:

- The gauging analysis will identify the costs of moving existing infrastructure to enable larger vehicles. These costs will have to be compared with the benefits they will permit.
- The gauging review may identify that certain routes, particularly diversionary routes, cause particular restrictions on the gauge. To achieve the necessary vehicle size to meet the noise requirements may lead to a vehicle with a limited number of operational routes.

- It may be necessary / beneficial to exceed the 'Lower Sector Vehicle Gauge' which the RSSB and Network Rail are trying to establish as a UK standard. Again, this may limit the operation of the rolling stock.

5.25. We considered other options but decided that we needed to conduct our own analysis before handing responsibility to suppliers. Please refer to the analysis of options on the gauging approach detailed in HS2-HS2-RR-PPR-000-000011.

> *Recommendation 9d: Passenger Interior Noise*
> *The requirement in the OTTR for 70 dB(A) LpAeq,T outside of tunnels should be retained.*

5.26. Feedback from Rolling Stock manufacturers, suggests that the interior noise level in the OTTR presents a challenge for CP and CC but is achievable.

5.27. HS2 is considering how to manage rolling stock noise levels inside tunnels and this will be detailed in the Train Technical Specification. Development will include further market engagement.

5.28. HS2 will develop other measures to supplement this limit, for example looking at specific limits on different characteristics of noise, such as tonality, loudness and sharpness.

5.29. **Other option(s) that were considered:**

Option	Reason for rejection
Relaxed Interior noise level	The level suggested is considered challenging but achievable. It aligns well to the interior noise level of recent rolling stock procurement and the desire to develop a world-class passenger experience. There is therefore no need to relax this at present
Use mandatory levels in standards	No mandatory standards provide limits for passenger interior noise

6. Ensuring fulfilment of RS&D Objectives and Success Criteria [5]

6.1. In order to enable the assessment of the options, and to support the recommendations within this paper, specific Success Criteria for the Material Technical Specification Parameters have been developed based upon the RS&D Programme objectives, included in Table 2 below.

6.2. The specific Success Criteria for the Material Technical Specification Parameters that underpin the options and recommended are presented in each of the Appendices that summarise technical considerations for each of the Material Technical Specification Parameters.

Table 2 - List of Success Criteria, referenced from HS2-HS2-RR-PPR-000-000005

RS&D Programme objective
Health, Safety and Security – The Rolling Stock programme will be designed, built and operated with world class health, safety and security standards
Environmental Sustainability – The Rolling Stock programme will deliver an environmentally sustainable solution and Rolling Stock operations will minimise impacts to neighbouring communities.
Journey Experience – The Rolling Stock programme will set new standards in passenger experience
Operations – The Rolling Stock programme will be operationally efficient and resilient.
Capacity & connected cities – The Rolling Stock programme will add capacity and connectivity, through meeting sponsor's requirements for reliable journey time and therefore being a catalyst for sustained and balanced economic growth across the UK.
Value for money – The Rolling Stock programme will deliver value to the UK taxpayer and passenger. The Rolling Stock programme will be affordable within the capital budget for each phase and be comparable or better than international benchmarks
Programme Delivery – The Rolling Stock programme will be delivered on time.
Strategic Alignment – The Rolling Stock programme will meet its stakeholder's objectives and the sponsor's requirements as set out in the Development Agreement, including supporting other HS2 strategies and goals.
Risk – The Rolling Stock programme will remain feasible and within control of HS2 and its delivery partners.

Development Agreement Implications

6.3. The recommended decisions in this paper support the fulfilment of the Sponsor's Development Agreement requirements.

6.4. Relevant Development Agreement requirements for each of the material technical parameters is detailed in the detailed supporting papers listed in Table 1.

Options Considered

6.5. In preparing recommended decisions for each Technical Selection Parameters, the best alternative options were identified and considered in order to ensure the most appropriate recommendation.

[5] HS2-HS2-RR-PPR-000-000005

6.6. These options have been identified and their reason for rejection stated within each topic heading within this document (sections 3 to 5). Further detail can be found in the supporting papers listed in Table 1.

Context of recommendation

6.7. This paper is one of a series of recommendation papers to be taken through governance prior to commencement of the Rolling Stock procurement process in March 2017. Table 1 sets out the other areas of the train technical specification where recommendations are being made within this time frame.

Business Case Considerations

6.8. Business Case impacts have been defined through consideration of the five case model detailed in the RS&D Objectives and Success Criteria, eB reference: HS2-HS2-RR-PPR-000-000005.

6.9. Each of the material technical specification parameters papers detailed in Table 1 has demonstrated how each recommendation for impacts on the Business Case.

6.10. The following sections provide a summary of impacts upon the Strategic, Economic, Financial, Commercial and Management (Deliverability) Case by exception.

Strategic Case

6.11. The recommended decisions across all material technical specification parameters ensure delivery of all Sponsor Requirements in the Development Agreement.

Economic case

6.12. The recommended decisions across all material technical specification parameters ensure delivery of the Economic case and Value for Money.

Financial Case

6.13. The recommended decisions across all material technical specification parameters ensure delivery of the Economic case and Affordability.

Commercial Case

6.14. As a general approach, it is considered inappropriate to pass risk associated with infrastructure enhancements to Rolling Stock suppliers, other than where such enhancements are of direct benefit to the supplier in delivering their scope in the most cost effective manner (for example, to allow re-use of proven Rolling Stock equipment). Any enhancements which are linked to delivery of HS2 scheme outcomes (such as improving journey times) will remain the responsibility of HS2 Ltd to define and deliver.

Deliverability

6.15. The recommended decisions across all material technical specification parameters ensure deliverability within the BL6 programme.

7. Assurance

7.1. The evidence developed in support of these recommendations includes both technical and economic analysis which come together to demonstrate that the recommendations presented align with the RS&D Programme Success Criteria. Inputs include market sounding information and conclusions from international benchmarking, both of which have been conducted by HS2 Ltd.

7.2. Table 3 summarises the residual risks against each topic area for which recommendations have been presented. This assessment of risk informs the level review that is required.

Table 3 – Summary of residual risks

Key Residual Risks	Probability	Impact	Risk Score	Residual Risks Management Plan
Specification Approach to Design Life				
Manufacturer or financier do not agree to the 35 year design life requirement	2 Low – In the most recent market sounding, suppliers have indicated that 35 years is acceptable now but may require some analysis	0 Nothing material – bidder may choose to be non-compliant and be marked down in the scored evaluation	0 Low	Design life to be detailed in the draft TTS for supplier engagement
Lost opportunity – we could have bought a cheaper train	2 Low – no evidence to suggest that shorter life would result in lower cost	3 Medium - Potential lower capital costs	6 Low	Further cost analysis benchmarking and constructing a whole life cost model
Train doesn't last 35 years – not designed correctly or loads are different	3 Medium - high utilisation	4 High Loss of service through premature fleet withdrawal	12 High	In service monitoring
Specification Approach to Train Control and Automation				
CCS TSI (ATO over ETCS) doesn't get ratified in time for implementation or ETCS development doesn't deliver HS2's required functionality	3 Medium – Development of CCS TSI requires agreement across Europe	3 Medium - HS2 solution becomes bespoke as development would need to lead the CCS TSI, this may lead to a situation where the HS2 solution needs migrate to a compliant solution later	9 Medium	HS2 to be represented on working groups to define ETCS solution. Rolling Stock and wayside signalling supplier required to be represented in development of ETCS.
Missed opportunity for higher Grades of Automation - mainline	2 Low – Conventional Network unlikely to migrate above GoA1 in foreseeable future as such drivers and cabs will always be required for Conventional Compatible Units	2 Low – GoA2 for Phase 1 does not preclude delivery of higher grades of automation later for Phase 2	4 Low	Not precluded for Phase 2
Potential benefits of depot automation may be underestimated	2 Low – Benefits have been developed in agreement between the Technical and Operational directorates within HS2 Ltd. Greater probability that costs are underestimated due to known gaps in costing information.	2 Low – Recommendation is to remain with base case. Additionally size of potential benefits seen as very low and as such missed opportunity unlikely to be significant	4 Low	None
Solutions selected is not deliverable with reasonable design effort	2 Low – Deliverability reviewed as part of selection process. Manufacturers will have opportunity to comment prior to PQQ and again prior to ITT.	2 Low – Fall back is a solution based on current practice, which is allowed for in current TSS and business case.	4 Low	Consult with manufacturers by releasing PQTS and TTS prior to formal issue and invite comments.

Key Residual Risks	Probability	Impact	Risk Score	Residual Risks Management Plan
Manufacturers put off by complex control requirements	2 Low – Deliverability reviewed as part of selection process. Manufacturers will have opportunity to comment prior to PQQ and again prior to ITT.	2 Low – Fall back is a solution based on current practice, which is allowed for in current TSS and business case.	4 Low	Consult with manufacturers by releasing PQTS and TTS prior to formal issue and invite comments.
Approach to Noise and Vibration				
Rolling stock does not support delivery of the ES overall noise commitments from HS2	3 Medium – Achieving lower than TSI noise pass-by performance for CC Rolling Stock will be a challenge	3 Medium – other elements of HS2 may be required to deliver additional noise mitigation to deliver the EMR commitments	9 Medium	Noise requirements in future procurements, e.g. Phase 2 Captive Verify noise model assumptions and update as required Draft PQTS supplier engagement

7.3. Technical reports directly contributing to these recommendations have been developed by HS2 Ltd or the RS&D Technical Advisor (SNC Lavalin/Arup). These reports are independently reviewed within the HS2 Ltd RS&D technical team, or the Technical Advisor's organisation, prior to a technical and analytical review taking place, as appropriate, within HS2 Ltd (Technical Directorate and Commercial Directorate). This review cycle has been summarised in Table 4.

7.4. The HS2 Railway Operations Directorate leads the RS&D programme and provides a review of the recommendations which offers a degree of independence from the task and also ensures that the recommendations align with the wider RS&D programme and with the emerging needs of the future train operator.

7.5. Table 4 explains the Line of Defence review that will be undertaken for each topic area.

Table 4 – Summary of Line of Defence reviews

Material Technical Specification Parameter	LOD Reviews
Specification Approach Design Life	LOD1 – SNC Lavalin LOD2 – HS2 RS&D LOD3 – Parsons Brinkerhoff to be completed on compilation of the overall RS&D strategy
Approach to train control and automation	LOD1 – HS2 RS&D/Technical Directorate LOD2 – HS2 Operations Directorate LOD3 – Parsons Brinkerhoff to be completed on compilation of the overall RS&D strategy
Approach to Noise and Vibration	LOD1 – HS2 RS&D LOD2 – HS2 Operations/Technical Directorates LOD3 – Parsons Brinkerhoff (as part of the strategy review) and ARUP will review the noise approach, providing both expert input and broad RS market knowledge input)