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Report

Necessities for future high speed rolling stock

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UIC High Speed

Contents

1 Introduction

1.1 Introduction

The railway sector is undergoing major changes both in Europe and the rest of the world. These include the relationship between railways and industry, intermodal competition, interoperability, liberalisation of railway passenger traffic in 2010 and the prospect of future development of High Speed in the USA, South America, the Middle East, India and elsewhere. This means railway undertakings will have to change their approach to tendering for new high speed rolling stock. As such, this report gives an overview of issues relating to high speed rolling stock which should be taken into account and recommends the establishment of common standards for high speed. It should be pointed out that any standards for high speed will depend on the geographical conditions of where the high speed train is operated.

* This report provides ideas for conventional rail-wheel high speed rolling stock and does not include Maglev.

**Abbreviations
RU: Railway Undertaking, IM: Infrastructure Manager, RSS: Rolling Stock Supplier, HS: High Speed, RS: Rolling Stock

1.2 Definition of HS

(1) EU Definition (DIRECTIVE 96/48/EC APPENDIX):

1. Infrastructure

a) The infrastructure of the trans-European High Speed system shall be that of the lines of the trans- European transport network identified in Article 129C of the Treaty:

-those built specially for High Speed travel,

-those specially upgraded for High Speed travel. They may include connecting lines, in particular junctions of new lines upgraded for High Speed with town centre stations located on them, on which speeds must take account of local conditions.

b) High Speed lines shall comprise:

Specially built High Speed lines equipped for speeds generally equal to or greater than 250 km/h,

Specially upgraded High Speed lines equipped for speeds of the order of 200 km/h, *Specially upgraded High Speed lines which have special features as a result of topographical, relief or town-planning constraints, on which the speed must be adapted to each case.*

2. Rolling stock

The High Speed advanced-technology trains shall be designed in such a way as to guarantee safe, uninterrupted travel:

-at a speed of at least 250 km/h on lines specially built for High Speed, while enabling speeds of over 300 km/h to be reached in appropriate circumstances,

-at a speed of the order of 200 km/h on existing lines which have been or are specially upgraded,

-at the highest possible speed on other lines.

3. Compatibility of infrastructure and rolling stock

High Speed train services presuppose excellent compatibility between the characteristics of the infrastructure and those of the rolling stock. Performance levels, safety, quality of service and cost depend upon that compatibility.

(2)Definition in Japan:

High speed lines are called "Shinkansen" (Shinkansen originally meant 'new trunk line' in Japanese).

The official definition of "Shinkansen" is "*a main line on which a train is able to run at over 200km/h along almost all the route" (the law: Zenkoku Shinkansen Tetsudou Seibi Hou).*

The Shinkansen network is a complex high speed railway transportation system with specific technical standards (i.e. dedicated high speed track without level crossings, standard track gauge and a special loading gauge). The Shinkansen train or Japanese HSRS, is a special class of RS that forms just one part of the overall Shinkansen transportation system.

(3) US Definition ("Vision for HIGH-SPEED RAIL in America", Department of Transportation):

-HSR – Express. Frequent, express service between major population centers 200–600 miles apart, with few intermediate stops. Top speeds of at least 150 mph on completely grade-separated, dedicated rights-of way (with the possible exception of some shared track in terminal areas). Intended to relieve air and highway capacity constraints.

-HSR – Regional. Relatively frequent service between major and moderate population centers 100–500 miles apart, with some intermediate stops. Top speeds of 110–150 mph, grade-separated, with some dedicated and some shared track (using positive train control technology).

Intended to relieve highway and, to some extent, air capacity constraints.

Whichever point of view is taken from anywhere in the world, HSRS means a type of RS which has the following common features:
- operates on systems specially designed for high speed (dedicated line or upgraded conventional line)
- is capable of running at over 200km/h

1.3 Current world HSRS

See Appendix.

2 General issues relating to high speed rolling stock

2.1 Development and design

Historically, it was mainly RUs in charge of new HS RS development and they worked closely with RSSs, as was the case for example with the Shinkansen, French TGVs and first and second ICE generations etc. RUs continue to be major players in the railway business and some railways still have extensive knowledge about railway technology. However, recent trends indicate that the role of RUs in development in Europe is decreasing. RSSs are therefore left to bear the majority of development costs, focus on their own priorities and end up interacting less with RUs. Liberalisation of the European market is set to intensify this trend and new entrants will be in an even weaker position to influence HSRS development.

At the same time, Japan presents a very different picture. There, RUs have a dominant role in development driven by the conviction that they are best placed to understand HSRS needs. As a result, development cost is often shared between the RU and RSSs.

Regardless of the situation, further HSRS development will still rely on a certain degree of RU and also IM involvement and knowledge to ensure that design is compatible with projected operational and maintenance conditions. Ideally, RUs should therefore have a clear idea of their projected requirements and RSSs should strive to provide value for money HSRS which meets these needs. Should the RSS take the lead in development, the RSS should try to predict RU - or future customer - demand. RSS products must meet RU and passenger expectations.

Notified bodies approving RS must understand the new technology being used.

In the development and design phases, it is important to predict the performance of expected rolling stock. This process relies on a number of complex variables such as braking distance, running resistance, dynamic behaviour, energy consumption, noise radiation, EMC, etc. Train performance should be modelled as accurately as possible in order to avoid lengthy test periods and adjustments before it can enter into service. Accurate prediction of such complex elements relies on a combination of calculation by computer simulation, subsystem bench test results and data from field tests.

2.2 Procurement

When RUs play the major role in HSRS development, procurement generally involves close negotiation with RSSs.

However recent liberalisation of the HS market in European countries means that HSRS is increasingly standardised and the role of RSSs is more and more important. A RU may in future be able to simply select off the shelf products, much like buying from a 'catalogue'. In such an open market situation, RUs would have to establish clear criteria to ensure selection of the right HSRS. Also, in EU states, international tendering is mandatory.

In Japan, given the close involvement of RUs in RS development, a RU places an order with a RSS which then manufactures it in partnership. Even in this case, the criteria stipulated when making the order have to be clear.

Criteria would include, life cycle cost, RAMS, passenger comfort, and other technical specifications. It would also include profitability in terms of:

Order volume (strong effect on unit cost),

Productivity of the RS (passenger capacity, maintenance intervals and method),

Track access charges to be paid to IM (different value in each RS).

When order volumes are large, the unit cost falls but technical and financial risks rise. Parameters for track access charges are a controversial topic in the EU so it may be logical to have a clear idea of the proportional actual cost from infrastructure, before launching a tender. It is also important for the criteria to meet local standards at least and satisfy RU quality requirements which may be more demanding.

When purchasing HSRS a RU could add options: for example, to have RS maintenance carried out by the RSS (see section 2.6). A RU could also choose leasing (see section 2.3).

2.3 Leasing

RUs may opt to lease rather than purchase RS, whereby the leasing company retains ownership of the HSRS, only leasing it to a RU. This is similar to the aviation business model and is widely used in UK. This arrangement helps to considerably reduce investment and will be especially advantageous if the RS is only to be used for a relatively short period.

2.4 Approval

Approval serves to guarantee HSRS safety. HSRS should be designed according to specifications which will make approval possible.

In Europe, HSRS is approved by authorised sector-specific bodies. Approval tests are conducted under the responsibility of the RSS. One major problem of approval is that it is time and money consuming. In fact the average cost of approval is estimated to account for approximately 10% of the purchase cost - and yet no standardised approval process exists.

Cross acceptance or standardised acceptance procedure is one path to reduce approval procedure related costs. Simplified processes should be created for approval of internationally operated HSRS.

New technology and open points which are not covered by standards need to be addressed with new approval criteria. Elaborate testing and research in this case has to be performed by RSSs, RUs or notified bodies.

The approval system may turn out to be an obstacle to introducing improvements and new technological developments for the additional approval cost. Any new approval system would therefore have to be designed to stimulate rather than prevent technological innovation.

In Japan, HSRS is approved by both RUs and national government. Normally approval costs are shared by the RSS and RU.

2.5 Deployment

Examples of total time to service of new RS appear in the Appendix. In the introduction of new HSRS series, the time between a decision to launch a tender (call for competition) and commercial operation of the first set is approximately 4-5 years including approval testing. It should be noted that technical development before tendering takes about 3-5 years for a new product. If the product already exists, that time is greatly reduced.

General elements in the process for a RU to deploy new RS are:

> Service planning (forecasting future needs), technical investigation/technical development, specification drafting, fixing tender criteria, tender (with/without negotiation with suppliers), contracts with suppliers, design by RSS (with RU participation if needed), approval tests by RSS or RU.

Other elements to be considered in parallel in the introduction of new RS:

> Facility planning for new RS, staff deployment planning, installation and construction of facilities, staff training

2.6 Maintenance strategy and technology

RUs are generally responsible for HSRS maintenance and as such carry it out themselves though some examples do exist where the RSS maintains the RS on the RU's behalf.

In certain countries, RUs and RSSs may set up a joint venture which will maintain the HSRS once it is built. The interest of such an arrangement is that the RSS can gather maintenance knowledge from the RU and the RU can keep up with new technology via the RSS. In some cases it has been found that the RSS had managed to generate new business this way and so capitalised on feedback collected through maintenance experience. Thus, although a RU's intention may only be to lower the risk of low labour efficiency, it should maintain in-depth knowledge about technical maintenance matters.

In the case of new entrants maintenance work may be mandated to an existing RU or RSS which has the required level of maintenance knowledge.

Maintenance of leased HSRS is normally carried out by the leasing company.

The interval between inspections today is fixed. It should be optimised to guarantee safety, reliability and reduce total maintenance costs. Also, new maintenance technology and criteria should be researched and acquired for more effective operation.

Currently, time-based maintenance for preventive maintenance is main stream. However, if health monitoring or checking of the train's state is used extensively, proactive maintenance replaces preventive maintenance. If a train is equipped with an onboard diagnosis system, data about the train's state is easily collected and analysed. This method can optimise maintenance work and reduce maintenance costs and is more effective for electric devices which are subject to sudden failure. Diagnosis may be performed remotely from a ground site which carries out remote maintenance. This makes corrective maintenance easier.

To keep maintenance cost down, the system's reliability should be high enough to keep running throughout maintenance intervals, known as, "train autonomy". The level of reliability will be determined by the operational strategy.

Maintenance rules must remain flexible to benefit from the introduction of new maintenance technology and methods.

Further on the issue of maintenance, RS may be used for infrastructure maintenance, and in some cases already is. Infrastructure maintenance monitoring and analysis systems could be installed on commercial RS, which would allow higher maintenance efficiency. Of course, such a system would have to be sufficiently compact and reliable.

In the case of minor maintenance work such as cleaning and waste disposal in particular, RS and maintenance facilities should be designed to enable this kind of task to be carried out speedily to avoid operational delays.

2.7 Life time and life cycle costs (LCC)

European countries normally estimate the lifespan of HSRS to be around 30 years. France and Germany estimate it at 30 years for example. Given that RS has such a long life, it requires mid-life renovation. In Japan, HSRS is assumed to have a life of about 15-20 years and is not subject to the same renovation.

The aim of renovation is to adapt the RS to customer needs, prevent deterioration and add technological innovations. For example in France, flexibility for the renewal of interior design and seat arrangements is very important to meet changing customer needs. The flexibility for renovation may be an important factor for RS destined for long life use.

When comparing renovation and the introduction of new series, several factors must be considered before opting for renovation: does a new series exist and if so, will it be introduced? What is the relative cost of renovation against introduction of the new series? Is it possible to introduce brand new technology or not, etc.

The strategy to introduce long life RS with renovation or short life RS without renovation will depend on the LCC, service strategy of the RU and so on.

LCC is central to evaluating cost effectiveness. The LCC encompasses all costs: purchase, operation and maintenance, renovation, scrapping and recycling. Train capacity is also an important factor for evaluating cost effectiveness.

Purchase cost includes not only production cost but development and approval test cost in many cases as well. As previously mentioned, order size strongly affects unit cost. C.f. "Cost of HSRS" Report 1999, UIC high speed.

LCC calculations are by definition hypothetical and do not reflect "real" costs. They may however be used as a basis for deciding whether or not to introduce certain HSRS.

Modular design makes renovation easier because parts can simply be replaced and this requires components with standardised dimensions.

The principle of Half-weight, Half-cost, and Half-life is applied to keep up with customer expectations of low costs. This principle depends on short rolling stock life cycles and as such reduces financial risks and outdated design due to long life. This method has been used for Japanese commuter train sets.

2.8 RAMS (Reliability, Availability, Maintainability and Safety)

RAMS is regulated as IEC 62278. All HSRS should meet RAMS criteria or at least its equivalent to assure high levels of service and safety.

The concept of RAMS is to adopt a product approach to achieve passenger satisfaction. A management cycle based on application, observation and improvement of RS is repeatedly implemented in a process which can change the design process and maintenance system of RS.

RAMS of a component can only be achieved with thorough design and after extensive post-assembly testing. Forecasting RAMS of RS at the pre-operation stage depends on the RAMS of subsystems and their system trees. Testing prior to beginning operations should obviously be as thorough as possible in order to ensure RAMS is at an acceptable level.

For stable operation, reliability and availability should be increased to the required level. Redundancy should be planned for the total train system, especially in the case of parts which are difficult to have redundancy such as mechanical components like bogies, doors, etc, the latter should be reliable enough not to affect operations.

2.9 Modularity and standardisation of train parts and components

Modularisation and standardisation would have a direct impact on the manufacturing cost of RS by virtue of lower design costs and standardised parts. Replacement of RS parts and renovation of RS also becomes easier. Standardisation is especially important for interface parts. Standardisation also facilitates entry of new suppliers onto the market which encourages competition and may reduce prices.

HSRS has to meet a series of operational specifications, for example, ISO, IEC, UIC leaflets, regional standards like ENs etc., and national standards. In European countries, TSIs determine requirements for cross border transportation. It should be mentioned that standards set minimum requirements for operation but it is up to the RU to consider other requirements in order to satisfy other customer needs.

Modular design will provide a wide variety of final products at low cost. As such a RU will easily find a product meeting its general need though it may need some compromise against overall need. It will also allow RSSs to increase production volume and cut costs significantly. As such, this concept could be profitable for both RUs and RSSs though the necessary systematic design may be costly.

Standardisation should leave room for technological progress and should not suppress innovation. Constant revision is a must in order to keep up with ever changing technology.

2.10 Compatibility with infrastructure

Generally, local standards determine compatibility between the RS and infrastructure interfaces. When a new HS system is introduced independently to an existing system, new standards can be implemented to optimise HS operation. Should new HSRS be introduced in an area where HS already exists, then it must be compatible with that system. In EU countries, TSIs must be complied with as a minimum requirement.

Optimisation of the system from a technical point of view can only be achieved if RUs and IMs take a holistic approach to the system.

The topics considered as the compatibility are, for example:

> Track gauge, loading gauge, train length, current collection, wheel/rail contact, pantograph / catenary contact, track dimension (especially in workshops which sometimes have tight dimension), platform height, aerodynamic effect, power/braking system, signalling and communication system, train control/diagnosis system, etc.

These topics are covered again later.

3 Basic operational aspects of high speed rolling stock

3.1 Train set formation and basic dimensions

3.1.1 Track Gauge

Standard gauge (1435mm) is the most commonly used track width today. However, Spain, Russia and Finland operate or plan to operate at 200-300km/h on broad gauge. An independent system free of compatibility constraints could be chosen for broad gauge in order to increase passenger volumes. However, this gain would be in part offset by the cost of special modifications required to adapt RS to the broader gauge and possibly high cost of building a different gauge HS system.

If there are different gauge systems in a network, the need to link different gauge systems will also probably arise. It is something which adds to cost and time delays because of the special variable gauge RS which would have to be built and trains forced to run slowly as they changed from one system to another. Fortunately recent technological developments which help to increase running speed at changeover and automatic variable gauge systems are reducing the significance of this issue.

Narrow gauge is considered to be a disadvantage both technically and economically (capacity per investment) by virtue of constraints due to component size.

3.1.2 Loading gauge

In European countries the UIC gauge (of which there are three sub-types: A, B and C; C being the largest) is broadly applied to RSs. The usual gauge used for new HS line is the C gauge. In Japan, the loading gauge for HSRS is the special Shinkansen gauge, which is 250mm wider than the UIC C gauge*.

Wide gauges help increase passenger capacity because of the width (5 seat rows are possible). Taller gauges like the UIC C (4650mm) gauge and Shinkansen gauge (4500mm) also increase capacity because it is possible to have double decks. The larger loading gauge may be considered as an option to maximise capacity and passenger comfort if the HS system is independent from the existing network.

If car length is shortened, the width of RS can be maximised to within the regulatory loading gauge because of the dimension at curve.

Aerodynamic issues arising from large loading gauges are mentioned in section 3.3.6 and 3.5.1.

> *Sweden, Russia, and China have adopted wider loading gauges than the major western European countries. In Spain, the HS line between Madrid and Barcelona was designed to the Shinkansen loading gauge.

3.1.3 Axle load

Axle load should be minimised to reduce infrastructure maintenance work unless this conflicts with safety and operational needs like anti-collision structure, signalling, and so on. To this end the weight of parts such as body shell, electric components, interior fittings, seats and so on should be reduced as much as possible. Total weight saving is easier if a single widely used part can be made lighter. Since bogies are by definition very heavy, simplifying their structure can be an effective way to reduce overall weight. Generally, non-articulated and EMU type structures have lower maximum axle loads.

Weight reduction also has a positive effect on energy consumption.

For safety reasons, wheel balance must be taken into account. It is therefore necessary to maintain the wheel difference ratio within a certain percentage margin.

3.1.4 Train length

The maximum length of a train in Europe, as stipulated by the TSI is 400m, which is the same as in Japan. This seems based on the maximum optimum length in practice. Of course longer lengths could be considered in the case of forecasting future demand increases.

Having same length trains (for example two 200m trains) operated as a coupled train set to adapt to changes in demand and line capacity ensures efficiency and flexibility. Mixed operation of long single sets and coupled short train sets already exists (ex.400m ICE1 and 2*200m ICE2 in Germany, or 400m CRH2 and 2*200m CRH2 in China).

Operations using trains of three coupled sets is possible (for example, 120m trains *3). This may prove to be a good solution for direct connection services with off-peak demand. One drawback though is that total capacity is reduced because of train nose size which takes up passenger space, and costs are higher because of the number of leading cars (which are more expensive). It may be possible to design a train configuration which can be separated into 1/3 and 2/3 (for example, 240m train + 120m train). The latter would be effective for the previously mentioned case since it would overcome the disadvantage of a three set train configuration and operate as 1/3 length, 2/3 length or full length depending on the different possible combinations of the 2 kinds of train set.

Noses on HS trains are getting longer which unfortunately diminishes capacity, given the maximum permissible length. So in the interest of optimising capacity the nose should be as short as possible.

From the commercial point of view, the capacity of one train set is crucial to determine the train length. The train set formula should also be determined from an operational point of view.

3.1.5 Car length

The basic car length on an articulated HS train is about 13-19m and cars on non-articulated trains measure about 25m. These again will be the optimum values relative to capacity and loading gauge.

In the case of shorter body structures, the train may have to be articulated to allow for an optimum number of bogies.

Again, if car length is shortened, the width of RS can be maximised to within the regulatory loading gauge.

3.1.6 Distributed/Concentrated

There are two types of train in terms of traction distribution: distributed powered and concentrated powered. Concentrated powered trains can be classified into three types. A general comparison appears in the table below.

	Distributed Power	Concentrated Power	Concentrated Power (one locomotive with fixed train set)	Loco Hauled
Propulsion system	Lower power and large number	Higher power and small number	Higher power and small number	Higher power and small number
Traction performance related to the number of powered wheels	Higher adhesion	Lower adhesion	Lower adhesion	Lower adhesion
Maximum axle load	Lighter	Heavier	Heavier	Heavier
Passenger capacity	Full	2 cars less than distributed	1 car less than distributed	1 car less than distributed
Noise in the passenger saloon	Larger	Smaller	Smaller	Smaller
Maintenance costs related to the number of traction motors	Larger	Smaller	Smallest	Smallest
Flexibility of train set	Lower	Lower	Lower	Higher
Redundancy of the main component failure (theoretical)	Higher	Lower	Lowest	Lowest
Change over between systems	More difficult	More difficult	Medium	Easier
Maximum speed restriction for running direction	No	No	Possibly yes in push mode	Possibly yes in push mode

The recent design trend of HSRS is towards distributed power. The latest HSRS designed by major European suppliers are distributed powered, and in Japan, HSRS has always been distributed power. The main reason for this tendency seems to be traction performance, capacity especially in European countries, and maximum axle load especially in Japan.

The type of system selected also depends on existing maintenance facilities. If the facility is particularly suited to one type, it is disadvantageous to select anything else.

3.1.7 Articulated/Non-articulated

Generally speaking, articulated trains offer several advantages: overall lighter train sets, lower cost of bogie maintenance (fewer bogies), improved ride comfort because of rigid train-set structure as well as some arguments to say that they are safer in the case of derailment.

Non-articulated trains have the advantage of having lighter axle loads, easy separation of cars for maintenance, easy rearrangement of cars as well as higher capacity for the same train length because there are less partitions.

Selection of one type of train or another will also depend on existing maintenance facilities.

3.1.8 Double decker trains

By and large, double decker trains increase capacity. Quantitatively capacity depends on the structure of the train set, i.e. floor height of the door (fitted for low platform or high platform), articulated or non-articulated, and concentrated power or distributed power.

Double decker trains by definition need stairs and in future, lifts will have to be fitted to improve accessibility.

Generally a double deck increases the axle load since structure and capacity are larger. A double deck also tends to weaken resistance to cross winds because of the height of the vehicle.

3.1.9 Floor and ceiling height

Floor and platform height must be compatible and accessibility should be facilitated by having flat floors.

To ensure accessibility, HSRS floor height is ideal when level with platforms. Some countries, Japan, China and Taiwan etc. already apply this principle.

In Europe, the minimum mandatory requirements are set out in TSIs. Should platform height vary greatly, compromise measures become necessary, such as installing steps. Suspension control may also compensate the height difference between platform and floor height.

The ceiling height should be calculated for comfort and for overhead luggage storage if necessary.

3.2 Basic performance

3.2.1 Maximum speed

Maximum speeds today vary between 240-350km/h on the majority of main lines and 200-250km/h on upgraded lines. The world's highest speed RS today is the CRH3 in China which can reach 350km/h. The maximum speed for newly constructed main lines will be 300-360km/h, with a step up to 400km/h for the following generation of line. Maximum speeds should be determined on commercial factors (travel time between cities), estimated cost (extreme high speed may not be economically feasible), and technical issues.

Currently, we can categorise HSRS on the market into three types:

-Extreme high speed (over 300km/h): running mainly on dedicated high speed lines. Several series are already operating and some are under development.

-High speed (240km/h-300km/h): commonest type of high speed train operated in the world today and running mainly on dedicated HS line.

-High speed for conventional lines (200km/h-250km/h): running on both dedicated high speed line and upgraded conventional line. A large share of this RS is applied tilting body technology.

3.2.2 Acceleration and deceleration

Given that the main aim of HS is to reduce travel time between two points, acceleration and deceleration performance is a particularly important factor to be taken into account for trains running short distances, having many stops, or running on lines with speed restricting factors such as curves.

Higher deceleration for emergencies should be taken into account when increasing safety.

3.2.3 Current collection

HSRS pantograph geometry must be compatible with the infrastructure where it is to be used. Contact performance should be excellent for high speed current collection and for preventing excessive contact wire and contact strip wear. It should be noted that replacing contact wires will generally be costly than replacing contact strips.

A holistic approach to optimisation of current collection system is all the more important when the IMs and RUs comprising the HS system are separate companies.

RS technology for stable current collection must aim for low contact loss rates avoiding excessive stress on contact wires and low contact strip wear by reducing arcs. Contact loss can be reduced by contact strip mass reduction, mechanical design of the pantograph mechanism and contact strip, and stabilisation of contact strip aerodynamic lift.

The number of pantographs should be necessary to reduce train weight, aerodynamic and contact noise, and production and maintenance cost. Ultimately single pantograph per train current collection is ideal. In such case, the current capacity must be considered for pantograph design and installation of back-up pantograph for system redundancy. Trains for multi voltage train will require single multi voltage compatible-pantographs.

The distance between the two pantographs attached to the roof has to be determined according to current collection performance analysis to avoid dynamic interference from mechanical point of view when two pantographs are in contact with the catenary. Electrically speaking the distance should be consistent with the design of feeding section.

For HSRS to run on non-electrified line, diesel powered HSRS is possible. However power performance is likely to be poor and it would be unfriendly to the environment. Though calculations for CO2 emission, energy consumption, and operation cost still be needed, electrification or introduction of electro-diesel hybrid system may be suitable.

3.3 Safety and security issues

3.3.1 Running stability

The HS TSI stipulates that trains must be stable at 110% of the maximum operational speed. Notwithstanding this percentage margin, RS must prove it has a safety margin for stable running at maximum operating speed.

The dimensions of the bogie such as wheel base, design and parameter of dampers and springs, etc must be thoroughly designed and tested.

The conicity might be reconsidered according to the wheel base of the bogie, maximum speed, and the track dimension for stability and lateral force reduction.

(See also sections 3.8.8 and 5.1)

3.3.2 Signalling

In-cab signalling is mandatory for HS system. In the case of dedicated HS tracks today continuous control systems like TVM in France, LZB in Germany, ATC in Japan, ETCS as a European standard, CTCS in China etc. are applied. In almost all these systems the permissible speed is not only indicated as a discrete value but also as continuous braking curve to permit high density operation and high ride comfort.

In the case of high density operations, performance can be improved with braking curves and mobile block sectioning. ETCS (level 3) in European countries and ATACS in Japan are examples of this kind of system. ETCS level 3 is destined to be used mainly in European countries and the next standard of European signalling system, and ATACS is currently being tested (only for conventional lines at present).

On board signalling systems must be compatible with all the lines on which the train runs. ERTMS, a common international signalling system in Europe, is being developed to simplify interoperability. However, until the latter is fully developed, trains will have to run with several on board systems, so signalling components will have to be integrated and compact in order to fit inside the RS.

3.3.3 Communication

In European countries, GSM-R is being developed and used as a part of ERTMS system for standard track-train communication. In Japan, the most commonly used system is LCX digital cable radio.

Communication systems should preferably be not only for operational use i.e. train staff and traffic control but for passenger service use such as internet. The system will require high capacity.

3.3.4 Crushworthiness (designs to prevent of loss of life)

In TSIs in European countries, certain rules already demand RS to have a minimum level of crushworthiness.

Crash safety is particularly important in the case of HSRS running on lines with level crossings. The train should be built in a way that ensures there is a crush proof survival zone that prevents loss of life to passengers and driver. This philosophy may increase the weight of RS and may not be feasible if the required energy level is extremely high. If RS runs on dedicated HS lines with high level safety systems then this is less of an issue.

When incorporation into RS design is not feasible (too heavy etc), crash safety should then be assured by the overall HS system, i.e. signalling system, track design, operation system and so on, and not only rely on RS.

3.3.5 Fire safety

Materials used in HSRS should be non-flammable or at least flame resistant. They should be also light weight, environmentally friendly, and economically feasible.

Evacuation rules should comply with regulations in force in the country where the RS will be operated. For fast evacuation, door size (wider is better), aisle size (wider is better), and layout of cabin (number of doors and large and breakable windows) should be considered as well.

3.3.6 Crosswind resistance

The risk of overturning due to crosswinds must be factored into the design equation due to operational conditions in high speed (running over viaducts, embankments etc). Further research remains to be done.

Common measures to counter this risk for RS include: reducing car height, reducing the height of the centre of gravity, rounding off roof edges etc. However these may reduce passenger comfort. Heaviness of RS can offer some advantages, though the same feature has its drawbacks too.

A common external measure is to build a line side wind breaker to reduce the impact of crosswinds on the train. This issue could be solved by crossed measures for infrastructure and RS.

3.3.7 Security

Some RUs already have railway station security systems. For RS, CCTV (Close Circuit TV) or other sensors may be installed to detect dangerous objects or suspicious persons during service. When such systems are in place, research should follow on incident prevention and processing of collected data.

3.3.8 Derailment

Derailment occurs for reasons which are either extraneous and/or inherent to the RS. Extraneous causes, such as landslides or level-crossing collisions, will not be discussed in this paper. Inherent causes here mean for example bogie part defects or bogie dynamics.

To assure the safety against derailment, the derailment coefficient should be found for each type of RS for the entire line along which it will be operated. The coefficient is related to many elements, the profile of wheel/rail, weight, weight balance, dimension of the bogie, running velocity, and so on. Verification standards have already been established in countries where HS train is operated and should therefore be respected. For higher speeds it may be necessary to revise these, which would require extensive field tests.

A RS part defect should not cause derailment. After changes to bogie design in particular, bench tests and field tests should be carried out thoroughly and carefully.

Maintenance of safety after derailment should also be planned. Some argue that articulated trains are safer in case of derailment (though the validity is not evident). One solution to guarantee safe conditions even after derailment is proposed to have a guiding device attached under HSRS axle boxes to avoid significant deviation from the track. This idea was implemented in Japan as a countermeasure to derailment caused by large earthquakes.

3.4 Environment

3.4.1 CO2 and energy

Reduction in CO2 emissions from HSRS is proportionate to the reduction in energy consumption. Various methods exist to reduce energy consumption: reduction of power unit energy loss, use of regenerative braking and reduction of running resistance. Better management of power units could be achieved by redesigning circuits and control methods. Adoption of highly energy efficient devices would also be effective in reducing energy loss. Smoother car body surfaces etc. diminish running resistance (see section 3.5.1). Reduction of weight is also effective. Energy savings on stand-by RS requires better management of main circuit systems, air-conditioning and so on. In the case of air conditioning system, better heat insulation helps energy efficiency.

In the case of competition between different operators on the same line, energy consumption meters, which can measure not only consumption but energy generation from regenerative braking, may be necessary to provide energy consumption data to IMs. Detailed measurement may motivate players to reduce their energy consumption.

Eco-driving may be incorporated into timetabling and be coupled with a driving support system for the driver to lessen energy use. ATO is also a possibility.

3.4.2 EMC

EMC must meet government and other regulatory requirements and it is important to test not only isolated components but also entire HSRS once it is assembled. Many tests must be conducted in a whole range of conditions (power, braking, coupling, and so on.) Further research to establish as set of general principles is expected to limit the need for testing. It should be noted RS must be designed to avoid harmonics which sometimes affect signalling.

3.4.3 Outside Noise

External HS train noise is classified as rolling noise, noise from mechanical parts like bogie parts, noise from electrical components like air conditioning and blower motors, contact noise from the pantograph, and aerodynamic noise.

Aerodynamic noise forms one of the main noise sources on HSRS according to research and tests so far. It stems from the pantograph itself, roughness of the car body, gaps between cars, the nose, the space around bogie, and so on. This can be reduced with smoother surfaces, using noise dampers, using aerodynamic parts, adding parts assisting smooth air flow especially around car gangways and around bogies, fitting noise insulation panels around pantographs and bogies etc.

Rolling noise (which is less of an issue at HS, in the case of Japan) may be reduced through measures applied at wheel/rail interaction level, in the form of wheel dampers for example.

Parts and components should be designed to limit structural noise as much as possible, such as reducing the number of fixtures with fans or blowers, for example, or by using noise insulation.

Good contact between pantographs and contact wires keeps arc noise to a minimum .

3.4.4 Ground vibration

Ground vibration depends on track side conditions, infrastructure, axle distribution in a train set and axle load. The most effective measure to tackle this in the case of RS is to reduce axle loads.

3.4.5 LCA

LCA is another important consideration for future HSRS. Further research and benchmarking in needed in this field.

LCA helps to establish whether the materials used in RS are environmentally friendly, recyclable or reusable. As a result, new recycling methods or reuse of certain materials have to be found, such as for plastic and glass which are difficult to recycle. Some heavy metals and liquids harmful to the environment should be prohibited.

Even though composite materials have been found to be difficult to recycle, current tendencies show that their use will increase in the future, and so disposal of them must be taken into account.

3.5 Aerodynamics

Aerodynamics is a key issue for HS trains.

3.5.1 Aerodynamic resistance

Reducing the loading gauge helps reduce aerodynamic resistance. Once again however, smaller loading gauges reduce passenger space affecting comfort and capacity. Advantages and disadvantages therefore have to be considered.

Wider loading gauges increases aerodynamic resistance because of the larger cross section perimeter. On comparison of two trains with the same capacity, a shorter train with a wider loading gauge and a longer train with a smaller loading gauge, the aerodynamic resistance of the shorter train may in fact be less because aerodynamic resistance depends more on the surface area of the train. Such comparisons can be made through simple calculations by formulas for aerodynamic resistance.

Smoother body shape, i.e. flat window, flat door, covered gap between cars, aerodynamic protuberances, covered protuberances, flat undercovers etc, also help reduce resistance.

Longer noses have a limited impact on aerodynamic resistance given that resistance is mainly from the body surface especially on longer trains. Resistance from rear noses and coupled noses also needs to be considered.

3.5.2 Tunnel micro-pressure waves

On lines where HSRS runs through a high number of tunnels, this issue becomes a problem. Lengthening the nose, optimising the nose shape and having a smaller loading gauge mitigate micro-pressure waves. However, these measures again reduce passenger comfort. A balance must therefore be struck to achieve optimum effect.

There is an idea that only leading cars are designed to lower the roof height or reduce its width to smaller clearance gauge.

3.5.3 Pressure fluctuation from passing trains running through tunnels

This problem increases when the train cross section increases in proportion to the tunnel cross section. This issue also affects ride comfort (see section 3.6.4).

General effective countermeasures to this are to lengthen the nose, smooth the car body and use a smaller loading gauge. However, longer noses and smaller loading gauges reduce passenger space. A balance must therefore be struck to achieve optimum effect.

In addition, the body shell including windows and door leaves must be sufficiently robust to resist repeated exposure to such pressure fluctuation. This is important especially for the RS running on lines with many tunnels.

Proper air-tightness of the HSRS is essential for passenger comfort. (See section 3.6.4)

3.5.4 Flying ballast

Certain HS trains sometimes cause ballast to scatter. The vortex created by the train is thought to be the cause of this phenomenon and may be related to the lower body structure. As a solution some aerodynamic parts are fitted to the RS to smooth air flow around bogies (Germany). Further research is necessary to be able to introduce measures at the design stage and avoid having to apply corrective measures after entry into service. Infrastructure solutions include lowering the ballast level of the track (Spain) and installing net covering on the ballast (Japan).

3.5.5 Ride comfort by aerodynamic fluctuation

Ride comfort may be affected by aerodynamic fluctuation in tunnels in particular. If this phenomenon exists, then further research still needs to be done on the subject.

3.6 Comfort

3.6.1 Ride comfort

Choice of proper primary and secondary suspension is fundamental for ensuring ride comfort. Now the majority of secondary suspension is air suspension. Active suspension (full active suspension or semi active suspension) is increasingly being introduced to control secondary suspension, mainly to reduce lateral vibration but which may also help to reduce vertical vibration. Research is being carried out to introduce active suspension to primary suspension too.

Reducing elastic vibration depends very much on how stiff the car body shell can be made. The natural frequency of elastic vibration must not coincide with the operational speed frequency.

Tilting body technology possibly causes a problem in terms of ride comfort (see section 3.6.3). Tests should be done well before introduction to commercial service.

3.6.2 Noise abatement in the passenger saloon

Materials and structure design for passenger cars should aim to dampen or cut noise emanating from the floor, windows, walls, ceiling and eliminate sources of noise generally. In the case of EMUs, noise abatement measures are especially important since a large number of noisy components are located beneath the passenger saloon. Air conditioning systems and forced ventilation systems are also major noise sources both at component level and because of the air ducts. Silent structures should be considered.

The standard to be met in terms of noise level should be determined by each RU depending on the quality of service the company wants to offer.

3.6.3 Tilting system

Tilting systems for better ride comfort in curves have already been introduced on HS trains as a necessary measure for running on conventional lines at HS. Although this measure may not be necessary for HS trains running mainly on HS lines, the latest Shinkansen (running on old HS lines) introduced a small degree of tilting by means of air suspension control in order to maintain running speeds through curves. So in the future we may see even HS trains running mainly on HS line, using such tilting technology to increase running speeds.

Several tilting train systems exist; natural tilting with a higher roll centre or forced tilting with actuators or air suspension. The ride comfort for each system is different. Ride comfort is not only important in ordinary curves but also in transition curves. Again, thorough testing must be performed before introduction into revenue service.

The loading gauge of tilting trains tends to be narrower and could deteriorate passenger comfort.

Another feature of tilting train is that although it may improve ride comfort, the dynamic impact on the track increases by virtue of increased speed in curves.

3.6.4 Air tightness

HSRS should be airtight to avoid exposing passengers to extreme pressure fluctuations. This is particularly essential for HS trains running through tunnels. Current HSRSs have onboard systems which close vents on entering a tunnel or remain airtight with continuous ventilation. The whole car body including doors must be well sealed for air tightness.

3.6.5 Air conditioning

Installation of air conditioning is vital for passenger comfort. The power of the air conditioning component should be determined by the climate where the RS will be operated. The function to control humidity would be an option especially for humid or dry country. Heat insulation of the car body is essential for the effective air conditioning. Air conditioning in the driver's cab is important because of the large window surface around the cab which transmits heat easily and also in order to comply with driver working environment requirements. Driver cabs should have independent air conditioning in many cases.

Ventilation systems are also necessary to avoid large pressure fluctuations in the cabin in tunnel sections. If there are many tunnels along the line then a continuous forced ventilation system, which ensures sufficient ventilation, or at least a system to shut vents before entering tunnels will be necessary.

An idea of air conditioning at each seat could be a solution for improving passenger comfort.

3.6.6 Extreme climatic conditions

HSRS will increasingly be operated in extreme climates – very high or very low temperatures, exposure to sunshine, snow and dusty conditions or dry or humid climates. For each case, further research is needed along with extensive field tests. Factors to be considered include:

For high temperatures:
Air conditioning performance, heat transmission, time required for preparation to enter service after train activation.

For snow and low temperatures:
Heat transmission, clearing of snow and ice to prevent damage to infrastructure and RS (this is more problematic on ballasted track), de-icing of mechanical parts (such as doors, bogies and pantographs), avoiding infiltration of snow into components, time required for preparation to enter service after train activation.

For dry or humid and/or dusty climates:
Sealing on components, filter attachment on components, air conditioning with humidity control in the passenger saloon, keeping electrical components dry to avoid electrical problems.

Sunshine:
Deterioration of certain parts (especially rubbers and plastics) and paint, excessive heat under sunshine areas.

4 Commercial and human factor aspects of high speed Rolling stock

By virtue of the increase in competition and customer demands, it is more and more important for RS to meet customer expectations. Similarly the RS environment should be as user-friendly as possible for staff working onboard.

4.1 Ergonomics (in general)

Ergonomics is an important factor for optimising human-machine system performance because it makes human beings central to design. It helps to improve safety and comfort for passengers including those with reduced mobility as well as working conditions for staff.

For RS to be used over a long period of time, anthropometry, i.e. evolution of the human body, should be taken into account. (For example, in Japan in 2006, it was established that the average height of the population had increased by about 3cm in 12 years.)

4.2 PRM (Persons with Reduced Mobility) - Accessibility

Factors which should be borne in mind to ensure accessibility and freedom of movement within the train especially for those with reduced mobility are:

> Flat floors, same floor and platform heights, mechanisms to reduce the gap between the train and the platform, widened doors to allow for wheels chairs, lifts for double decks, fastenings to secure wheel chairs in place, properly equipped rest rooms, visual and voice guidance etc.

There are no specific requirements under this heading, since so much depends on the society and policies in the country. In many cases there may be violation of these requirements for the sake of train capacity, however, consideration for PRM is set to be of growing importance for future HSRS.

4.3 Driver desk and cab

Analysis of current and future tasks should determine the design of the driver desk. Analysis is all the more important when new technology or interfaces are introduced.

Given the increasing number of functions required for interoperability and the decrease in space due to nose aerodynamics, priorities for design will be: ease of operation, prevention of operational errors, ensuring sufficient front vision, reducing driver fatigue, noise abatement and ensuring sufficient space for the driver. Designs can be tested using mock-ups.

The driver desk may have to be designed to be easily interchangeable to follow upgrades of driving components.

Standardisation of devices used by drivers may be necessary to reduce driver workload and operational errors. For interoperable trains, the design should be standardised for all countries where the train is in operation.

Nonetheless, a standardised driver's desk may not be technically optimal since a standard may be the result of too much compromise among several countries. What is clear is that the search for optimal solutions will have to continue.

Automatic train driving systems (or automatic train operation: ATO) already used for urban transport in some cases could be applied for dedicated HS system with the necessary safeguards to guarantee safety. The job of drivers on such trains would then be more service orientated. Moreover, ATO should not have a negative influence on energy consumption.

4.4 Cabin design

Cabin design is directly related to passenger comfort and affects an operator's image and profitability. Also the design strongly depends on the policy of the RU.

4.4.1 Capacity

Capacity is one of the highest priorities in cabin design. Higher capacity is an advantage for profitability on a RS, so long as it does not infringe passenger comfort. For example, service facilities such as a restaurant car reduce total capacity, but may be unavoidable, if it is required by the RUs policy.

Widen body can effectively increase capacity by adding a seat in a row. For example, when car body width allows seating arrangement can be 2+2 rows in 1^{st} class and 2+3 rows in 2^{nd} class with enough passenger comfort. In Japan, such configurations are applied and 3+3 seats are also applied especially for short distance transportation.

Double decker structures increase capacity, which depends on component layout and the train structure such as articulated or not.

4.4.2 Seating

Seating and service category

Seating in HSRS today is either by compartment, facing, in rows or a mixture of these three.

Preferences depend on the country and type of service. Row seating appears to be the most popular choice generally, and for very long distances, compartments - especially for personal use or small group use - will be still the preferred choice for customers.

Currently most HSRS offers two classes and in some countries, three. Introducing three classes has been cited as being an effective way to differentiate railway services from air transport.

Differentiation between classes, aside from name alone, may be based on criteria such as, silent coaches (no mobile phones, no announcements), marketing channel (normal TGV and iDTGV in France for example), personal/business or family oriented, and so on. Seating arrangement will reply on the criteria set for the above.

In China, HS sleepers exist for long distance services (ex. Beijing-Shanghai). Although such specialised RS may reduce operation efficiency - it may be inevitable for long distance service.

Flexible seating

Flexible seating is an idea of easy re-arrangement of seating. One example of flexible seating is the use of a rail fitted to the floor with seats which can be fixed at the desired point and thus changed during a refit.

Seat dimension

The seat pitch in 1st class should allow most people to stretch out their legs in front of them. 2nd class provides knee space for the average individual even when the seat in front is reclined. The width of a seat in 2nd class should be of average shoulder width at least. Depending on the class of service, seats also need to recline, and some should be fitted with head, foot and arm rests. In any case sensor tests can be used to help determine the seat structure.

Rotating seats provide extra comfort for those passengers who dislike travelling with their back to the travel direction. In some countries rotating seats exist. In Spain, staff rotate the seats at the departure station. In Japan as well, staff rotate the seats by hand or automatically. Passenger can also turn the seats easily if necessary.

As it is assumed that most people will use a laptop, the flip down or flip up table design and location of power sockets and wired or WiFi internet connections should take this into account.

4.4.3 Windows

Larger windows with narrower frames create more noise, heat, sunshine and weaken the vehicle body but have the advantage of producing an impression of space and improving the view from all seats.

To maintain high visibility from all seated positions, it is better to determine the location of windows after the seats have been arranged. For example, on the Shinkansen each seat is designed to correspond to a window. However this makes seating re-arrangement during renovation difficult.
Narrow space between windows improves visibility in the case of flexible seating or in restaurant cars, though this may be counterproductive in terms of rigidity of the body shell.

4.4.4 Doors

HSRS today has a pair of doors for every 30-90 seats. Shorter distance between doors improves accessibility and reduces boarding and disembarkation time at stations, which helps reduce stopping time and evacuation time in case of emergency. However, more doors mean reduced capacity.

PRM and the possibility of voluminous luggage must be borne in mind when calculating door width.

In the case of large gaps between the platform and the train (such as curved platforms or small train loading gauges) extendible steps may have to be fitted for better accessibility.

4.4.5 Toilets

By and large, current HSRS has one toilet per car. There may be a minimum of one toilet facility for PRM per train. For more comfort, there may also be baby-changing tables or spaces for applying makeup.

The water and waste tank capacity and running time between service stops are mutually decisive.

Toilet should be designed to keep clean as easy as possible. Design issues like component arrangement and material selection should aim at easy maintenance and wear resistant. Moreover, lowering LCC should be taken into account.

Biochemical processes have recently been developed for the disposal of sewage. This solution may turn out to be both eco-friendly and facilitate operations.

4.4.6 Luggage storage

HSRS currently provides overhead, end of saloon (vestibule) and floor storage for luggage. Storage close to the passenger is preferable to avoid lost luggage. Floor storage uses up considerable capacity so overhead storage is probably the best solution for small items.

4.4.7 Cleaning

Each car may need to be installed with sockets for cleaning equipment.

Innovative materials or coverings can contribute to make cleaning easier.

Robots can be used to clean floors. Seats with cantilever legs facilitate floor cleaning.

4.4.8 External design

External design of HSRS is important for image. Engineering requirements will have a large impact on the external appearance of HS trains, so close cooperation is required to meet engineering and design needs.

4.5 Passenger services

4.5.1 Information network

Railways will eventually have to provide some sort of local network facility, as exists for homes and offices. This would also enable railways to positively differentiate their services with airlines.

Games, videos etc. could be offered as entertainment services, with movies offered on long distance trips via personal screens in the seats. Korea already has a train service with an on board cinema.

In addition, there is an idea to introduce a service giving information about the destination and traffic etc. which the passenger would be able to access at any time. It is to say travel support system. Implementing such a service would require the development of a special system and hardware.

4.5.2 Catering

There are two catering options: a restaurant and buffet service with dedicated space or an in-seat (trolley) service. The option selected will depend, among other things, on the travel distance and time, number of stops, demand for such a service and the train capacity (restaurant cars use up space). Also it strongly depends on the policy of the RU. It should be mentioned that catering services require huge logistical back-up facilities.

5 Other technical aspects of high speed rolling stock

5.1 Body and bogie structure

Most current HSRS is made from aluminium alloy, steel and stainless steel. Generally aluminium is expensive but is light weight. Steel is cheaper but has low endurance (high maintenance cost) and is heavy. Stainless steel can be used to construct a light weight structure at low cost, but is difficult to make airtight and has lower design flexibility, for the nose in particular. For light weight structures, use of carbon composites, which are already used on some HSRS as a structural component may be extended. Aluminium honeycomb is also used on some HSRS. It should be noted that these new materials generally have a high cost and must need thorough tests for safety.

Crash safety, usually comes in the form of a crash proof zone at the back of the driver's cab. Providing such protection has to be subject to a weight cost and risk analysis and must comply with regulations. (See also section 3.3.4)

To increase ride comfort, the structure should be as stiff as possible in the both case of bending and twisting and dynamic analyses must be made to avoid resonance. To increase resistance to bending, it is better to avoid placing doors towards the middle of the body.

The safety and reliability of bogies needs to be established through bench and track tests. The bogie is one of the heaviest components on RS, which means that the weight of some parts may have to be reduced – such as bearings, axles, wheels, gears, brakes etc. so long as the level of safety or reliability is not affected. Generally speaking, the simpler the bogie structure, the lighter and more cost effective it will be.

Given the bogie's central role in running safety, a large number of sensors can placed on the bogie to measure status parameters such as temperature, vibration acceleration, structural safety, and so on. The sensors themselves as well as the overall system will need to be well tested in the field to avoid later problems in operation. Radio communication can be used instead of wiring to make placement of sensors easier and improve reliability. Maintenance management will be improved if such kinds of data are collected. (See also section 2.6)

The location of components and their design will depend on the train set's composition, the weight balance of RS and maintenance considerations. For components located under the floor, extra factors should be borne in mind such as ease of access, detachment and replacement for maintenance, from which side it should be accessed etc. Location will be a factored in when determining maintenance policy, method, and facilities.

It would be better to avoid installing components on the roof in order to maintain a lower centre of gravity.

5.2 Power and Braking systems

In recent years, thanks to progress in the field of power electronics, HSRS has gradually been equipped with new technology, controllers, devices and motors which have improved energy efficiency and reduced maintenance costs. AC motors with IGBT / VVVF controllers are now more or less main stream. The most common type currently in use - AC motors - include induction motors and synchronous motors. Recently synchronous motors with permanent magnets have been introduced. Each type has its advantages and disadvantages in terms of weight, efficiency, and controllability. Linear motors may be a possibility but will not be widely used mainly for reasons of cost and compatibility with the existing infrastructure.

In terms of main circuit system equipment heat capacity should be considered. Special cooling systems such as blower-less (without fan) or pump-less systems for cooling liquid may be worth looking at to lower maintenance costs, weight, and noise.

Regenerative braking is essential to reduce energy consumption and may even be used instead of mechanical brakes for stopping the train, to help reduce maintenance costs related to the latter. Mechanical brakes however would still be necessary as a backup system in an emergency. Rail brakes can reduce the stopping distance in an emergency: it generates a higher friction force than simple rail / wheel contact, but weight and possible negative impact on rail and signalling are drawbacks. Aerodynamic braking is an effective means for braking which does not depend on rail/wheel friction and is more effective for higher speeds but uses up passenger space for installation and increases total weight. A simple alternative then would be to introduce a device for increasing rail/wheel adhesion, such as ceramic particle jets.

The use of technology to obtain optimal traction and brake distribution in a train set may be necessary to improve a train's traction and braking performance achieved through more effective use of maximum friction forces which may otherwise suffer from uneven distribution. The friction force is of course nearly proportional to the axle load, then the traction and brake system should be included the measurement of the weight. Anti-lock / anti-skid functions are necessary to avoid wheel and rail wear.

5.3 On board train control and information systems

Recent trains are installed with on board control and information systems which control, monitor, diagnose and display the status of the train and its components. It may be able to integrate the signalling system and communication system. These systems may be likened to the "brain" and "nervous system" of a train.
Such systems allow:

Better train control
Better train service on board
Better interface on board for operational staff and passengers
Efficient management and improvement of operations
Efficient management and improvement of maintenance
Efficient improvement of RS design

Functional integration will add new value to RS.

Integration of functions may reduce the weight of train by reducing the amount of wiring and controllers for each component.

The interface between the system and components should be unified for the system integration.

The system should be robust against failure and adequately redundant given the key role it plays for operations.

5.4 Other equipment

5.4.1 Auxiliary power units (APU)

APUs mainly provide power for service related equipment. The capacity of an APU should provide enough power for every seat-side plug. The APU should also have enough capacity to provide power to all necessary components when the train stops accidentally. In case of an emergency such that power supply to the train has shut, the APU should provide power to at least the emergency lighting, toilets and communication devices.

5.4.2 Compressors

Pressurised air is broadly used as a power source for mechanisms like brakes, doors, etc, because such system can be simply constructed. However, the compressor deteriorates ride comfort because of its vibration and needs constant maintenance. RS without compressors and air systems may be replaced with motor actuators etc.

Development of compressors producing little vibration or insulated against vibration will be necessary in the case of their installation near passenger compartments in particular.

5.4.3 Automatic coupling systems

To guarantee flexible train services, there must be a connector system for easy coupling and decoupling for both mechanical and electrical couplers. Of course, the train control system should be compatible with the coupling system employed.

To increase reliability and avoid electrical system errors, electrical coupling using wireless data transmission could be introduced avoiding physical intervention.

The coupling system should be designed to be coupled with other types of train to enable other trains to be rescued and, if possible, to allow other forms of revenue service.

6 Conclusion

This report aimed to give a general overview of issues which should be taken into account for future high speed rolling stock.

Chapter 2, presents the needs in terms of business process and other general issues such as RAMS and standardisation.

Chapter 3, lists the necessities in basic dimensions in train design and planning.

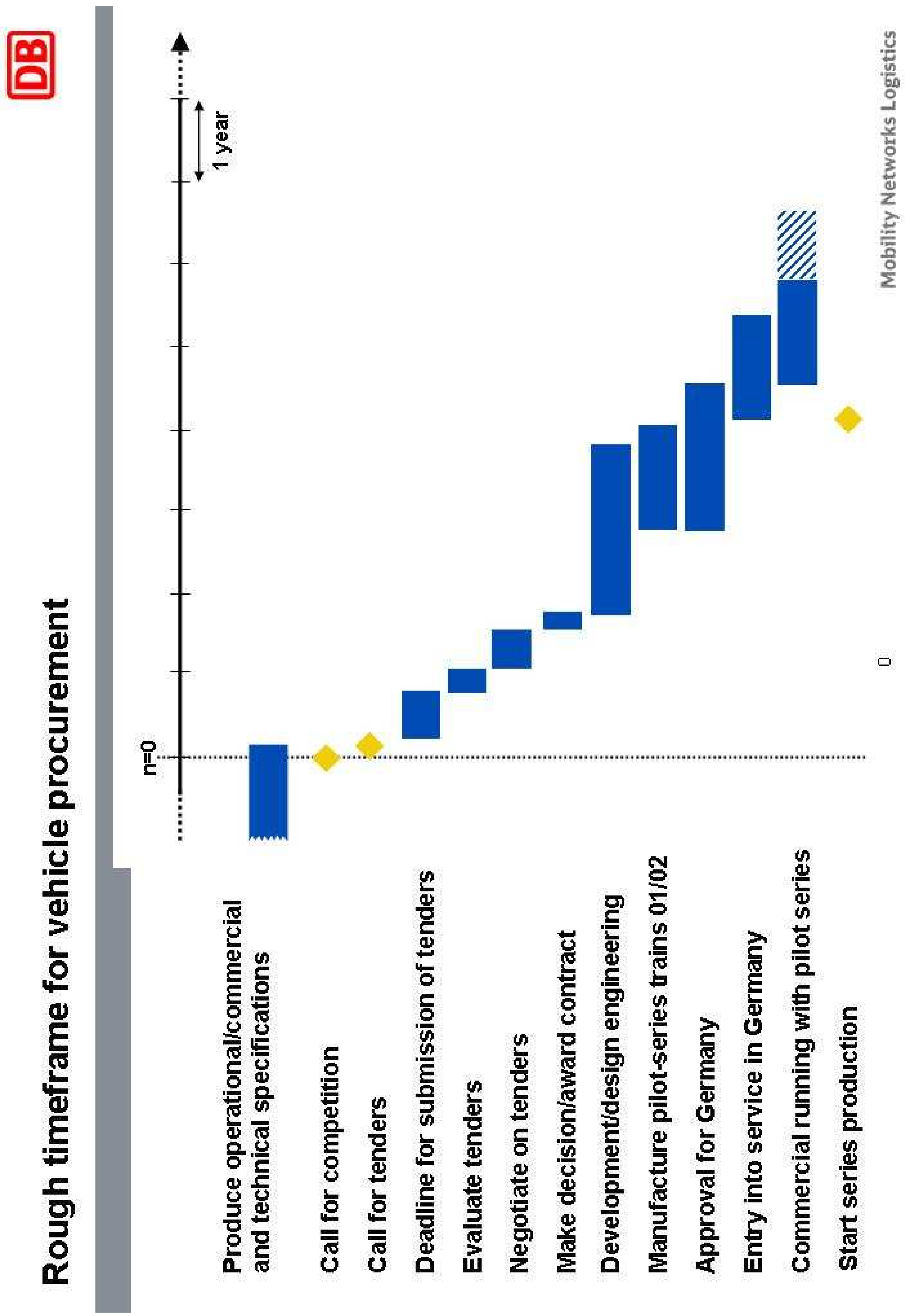
Chapter 4, lists the necessities from a commercial and passenger point of view

Chapter 5, lists other special technical issues.

This study encompasses all the possible demands which could be made of future HSRS. It is hoped that it will be of help to RUs when contemplating the introduction of new HSRS.

7 Appendix

-Current high speed rolling stock
-Examples of timetables in introducing new high speed rolling stock


Rough timeframe for vehicle procurement
Produce operational/commercial and technical specifications
Call for competition
Call for tenders
Deadline for submission of tenders
Evaluate tenders
Negotiate on tenders
Make decision/award contract
Development/design engineering
Manufacture pilot-series trains 01/02
Approval for Germany
Entry into service in Germany
Commercial running with pilot series
Start series production
n=0
1 year
0
Mobility Networks Logistics

Rough example of schedule in introducing new high speed train in Japan