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Transport

Rail Technical Strategy

July 2007

Department for Transport

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Contents

1. Executive summary

1.1 The Department for Transport (DfT) has led the development of this first version of the Rail Technical Strategy (RTS) through an open process of engagement with the rail industry. Network Rail, passenger and freight operators, rolling stock companies (RoSCos), the Railway Industry Association (RIA), the Rail Safety and Standards Board (RSSB), the Office of Rail Regulation (ORR) and the devolved administrations have all contributed. The RTS is published with and should be seen in the context of the 2007 Rail White Paper – *Delivering a Sustainable Railway* – which identifies the future needs that the railway is likely to meet over a planning horizon of 30 years. Over this period the railway will have to expand its capacity to meet demand, reduce its environmental impact, meet increasing customer expectations for reliability, comfort, safety, security and information, whilst at the same time continuing to improve its cost efficiency.

1.2 The RTS brings together a long-term vision of the railway as a system, creating a target for development to meet these challenges, seeking to optimise the use of existing technology and predict the impact of new technology. The RTS identifies the following long-term themes for change, which the industry should start working towards now:

- **Optimised track–train interface:** Light but strong rolling stock running on precisely-engineered, accurately-maintained track, reducing energy demand, track maintenance cost and noise;
- **High reliability, high capacity:** World-class reliability of both infrastructure and rolling stock. Infrastructure designed on lean principles with minimal trackside equipment. Intelligent infrastructure and intelligent rolling stock, each able to monitor the other and predict incipient failure;
- **Simple, flexible, precise control system:** Communication-based cab signalling to reduce infrastructure complexity and cost, as well as improve flexibility, combined with an intelligent management layer to offer precise control of train movement through the network, allowing energy efficiency to be improved and full potential capacity to be realised;
- **Optimised traction power and energy:** Regenerative braking on all trains, whether on the electric network or through onboard energy storage. Better use of existing electrification and selective extension where justified by business need. Bi-mode trains capable of running on or off wire, based on energy storage and with on-board power only where needed;
- **An integrated view of safety, security and health:** Improved detection of obstruction, intrusion and abnormal behaviour at all boundaries of the system, combined with better management of response to both safety and security threats and, in the long term, recognition of the need to reflect public health concerns in the rolling-stock surface materials and air conditioning;

- **Improved passenger focus:** Exploitation of ticketing, passenger flow, train movement and train load data to give high-quality information to passengers throughout their journey. Use of the same data to optimise controller response to abnormal traffic or passenger-flow conditions;
- **Rationalisation and standardisation of assets:** A rationalised approach to asset specification, with greater use of modular and 'commercial off-the-shelf' (COTS) equipment, covering industry-specific assets such as rolling stock based on a whole-life, whole-system cost approach across all industry partners;
- **Differentiated technical principles and standards:** Application of differentiated technical principles and standards to railway routes based on predicted traffic type and usage, allowing cost efficiency to be optimised whilst maintaining interoperability for passenger trains and access for commercial freight to all areas of the network where there is a reasonable expectation of need.

1.3 Many of the changes, particularly in the customer-facing area, will be realised through 'natural' incremental change mechanisms in response to current incentives and business needs. However, successful implementation of the RTS will depend upon Government and industry together taking a whole-life, whole-system cost approach in exploiting the opportunities presented by renewal of major assets and major enhancement projects.

1.4 The RTS includes a route map of change that not only identifies the major opportunities in terms of asset renewal and enhancement over time but also shows the research and development needed to support those opportunities, bringing together the themes for change into a change programme that can be actively managed.

1.5 The major opportunities that arise are those in which the industry is already active: in the rolling stock area, the Intercity Express Programme (IEP) being led currently by the DfT, the New Generation Multiple Unit programme which is currently still in its inception stage and the possibilities for use of existing tram–train technology for lightweight urban routes.

1.6 Research has already started to influence change to train and track characteristics through the Vehicle–Track Interaction Strategic Model (VTISM) sponsored by the Vehicle–Track System Interface Committee. European research (LITE and INNOTRACK projects) supported by all UK industry parties will further inform future specifications for both track and train from about 2009 onwards. Rolling stock reliability will build on the base established by National Fleet Reliability Improvement Programme (NFRIP). Network Rail has the tools to establish the long-term target reliability for both future trains and future infrastructure and has started to apply this to major projects such as Crossrail and Thameslink. This work needs to be expanded to cover routes such as Great Western.

1.7 The Network Rail Intelligent Infrastructure initiative, to which RIA members have contributed many ideas, is also important, and this links in with the new engineering data centre being developed at Derby. Better timetabling based on an accurate data model of the network is also being addressed by Network Rail.

1.8 As far as control systems are concerned, the European Rail Traffic Management System (ERTMS) is the key supporting technology, and the National ERTMS Programme, which has been developed by Network Rail into a model for cross-industry collaboration, is planning to fit all high-speed lines and many lesser routes within the timescale of the RTS. However, ERTMS is not yet fully consistent with the vision and needs development both to add the driver advisory speeds function and to progress Level 3, which further reduces the need for trackside infrastructure.

1.9 The immediate opportunity in power and energy is the implementation of regenerative braking for vehicles which are already capable, and the industry's positive response to this challenge over the past few months has been heartening. For electric railways, energy metering is the next important step, and DfT and the Association of Train Operating Companies (ATOC) are working together in this area on a trial project with active support from Network Rail. Biofuels are being pursued by several TOCs and present few technical challenges. In the medium term, hybrid (energy storage) traction development is a more important area. The hybrid HST power car developed for use on Network Rail's New Measurement Train is one example of several industry initiatives in this area that need to be developed rapidly to the stage of useful products in order to meet deadlines for new rolling-stock delivery. In the longer term, decisions on further electrification will depend upon the relative rate at which the carbon footprint of electricity generation declines and the rate at which options become available for low-carbon self-powered trains. Research into hydrogen technology is best pursued at European level, with the UK continuing as an active partner in collaborative European research.

1.10 The issues of safety and security have historically been separated in the railway industry's psyche, but success in reducing operational risk, so that the largest residual safety risks arise from intrusion, together with the increase in the security threat, are driving convergence. Network Rail is actively investigating the reduction in level-crossing risk through obstacle detection, and surveillance technology has obvious applications in both advance detection of safety failures and in detection of abnormal behaviour. These technologies are advancing rapidly.

1.11 Initiatives in passenger and train flow data need to be better co-ordinated. DfT and ATOC are taking forward smart ticketing, Train operating companies are working individually on passenger loading and information systems, and Network Rail is developing a new train location system in an initiative supported by ORR. This area will change very rapidly over the next 10 years, and the need is for agreement of common requirements and structures rather than technological research, as the technology already exists.

1.12 The planned application of differentiated railway principles and standards is a difficult initiative, both because industry culture does not support this kind of planned change and because there are potentially divergent interests involved, particularly in terms of open freight access to rural lines. The key first step is to gather the compelling evidence that illustrates the relationship between whole-life cost, axle load and speed, and then to develop solutions (for example tram–train) that are capable of exploiting the benefit and inter-operating with normal traffic.

1.13 Overall the RTS demonstrates how the future demands and key drivers may be addressed though a combination of existing and future technology that will meet changing passenger expectations by improving the attractiveness of the rail mode and improving its environmental performance to maintain its advantage over less environmentally-friendly competition. The DfT will continue to engage with all industry partners and stakeholders to encourage and support research, encourage alignment of incentives through the ORR and facilitate cross-industry programmes and projects that move the industry in the direction of minimised whole-life, whole-system cost. The RTS is intended to be a living document, owned and updated by the industry in response to future technology development and results of ongoing research. The agreed vehicle for this is the Technical Strategy Advisory Group, the remit for which has already been approved by the RSSB Board and which will include senior technical representatives from the DfT, Network Rail, passenger and freight train operators and suppliers, as well as RSSB, ORR and academia.

2. Introduction

Purpose of the Rail Technical Strategy

2.1 In July 2007, the Secretary of State for Transport issued a Rail White Paper, *Delivering a Sustainable Railway*, identifying the future needs that the railway is likely to have to meet over the next thirty years and incorporating the first High-Level Output Specification (HLOS). The HLOS specifies the outputs (in terms of safety, service performance and capacity) that the Secretary of State wants the railway industry to deliver over the period from 2009 to 2014. The Scottish Ministers have a similar duty in providing their own HLOS setting out what they want to be achieved for the railway in Scotland.

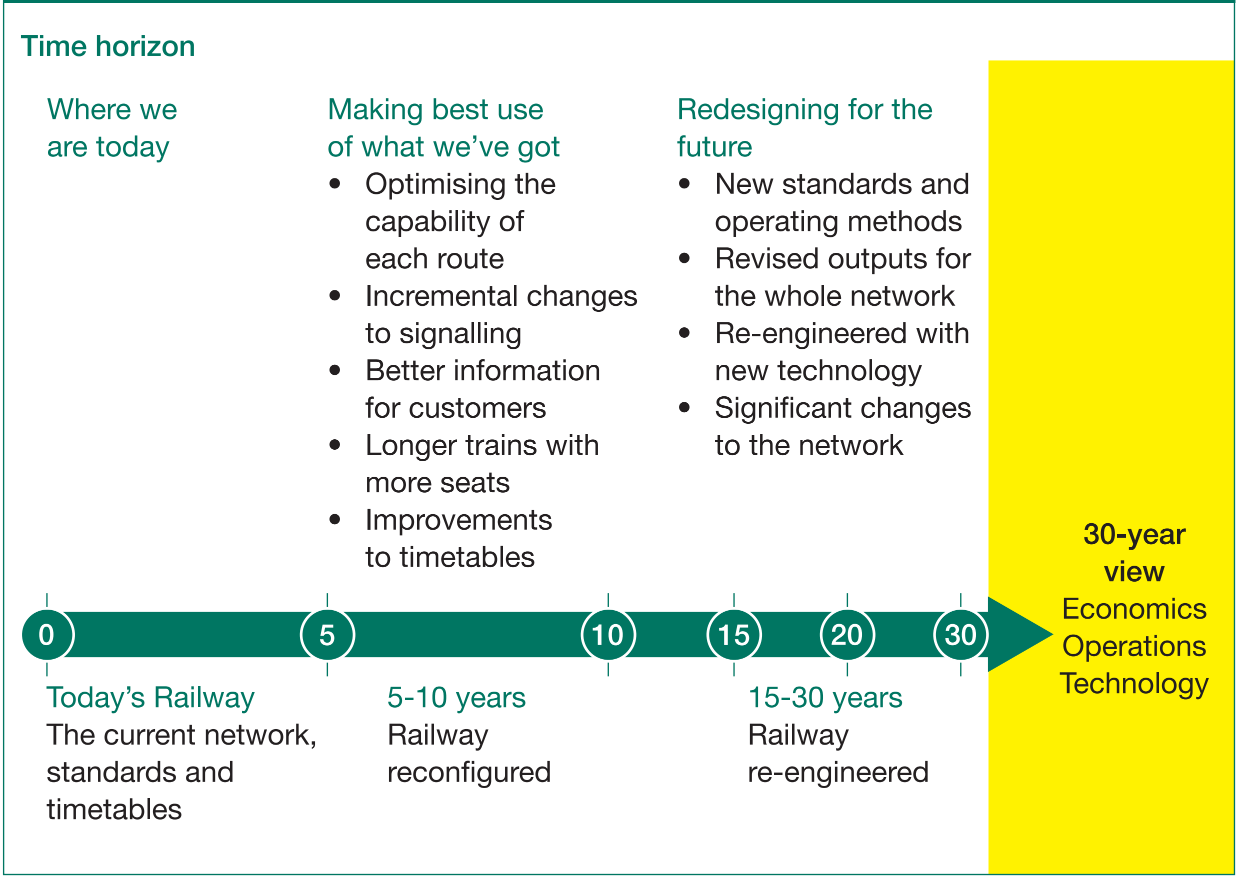
2.2 The industry's response will define the changes to the railway network that are needed and can be delivered, within affordability constraints, over the next seven years to meet the outputs specified.

2.3 The planning cycle is intended to repeat, with a new HLOS every five years. However, it is clear that to meet long-term needs for increased cost-effectiveness and capacity, reduced environmental impact and improved service to customers, the railway will need to change radically. The railway is a complex engineering system with long-life assets, and delivery of such a change requires an engineering-led vision of the railway, embodying both changes to the system using the best of current technology and a prediction of the changes that may be brought out by new technology (Fig. 2.1).

2.4 The purpose of the Rail Technical Strategy (RTS) is not only to establish and document an industry view of the technical changes that need to be made to the railway, but also to create a 'road map' showing how change can be achieved through:

- Creation of appropriate incentives;
- Appropriate standards and guidance for the specification of asset renewal;
- Harmonisation of objectives for major projects;
- Definition of key priorities for long-term research;
- Helping to shape Britain's response to European initiatives;
- Application overall of a whole-life, whole-system cost approach.

Figure 2.1: **Developing and delivering the change**



Ownership

2.5 The purpose of the RTS is to provide advice and guidance. It is intended to form a basis for action, but not through legislation. Strategic change needs joined-up action across the track-to-train boundary, driven by long-term needs. Ownership of the RTS must therefore be joint, engaging both Government and industry. The Department for Transport (DfT) has led production of this first version of the RTS through a continuous and open engagement process involving all industry parties including Network Rail, passenger and freight operators and their associations, rolling-stock companies (RoSCos), suppliers through the Railway Industry Association (RIA), Rail Safety and Standards Board (RSSB), the Office of Rail Regulation (ORR) and the devolved administrations.

2.6 Ownership of development and delivery resides with the owners and operators of the railway. The Technical Strategy Advisory Group (TSAG) of senior industry executive staff with appropriate expertise and experience will develop and champion the implementation of the RTS, advising and supporting further communication, overseeing strategic research, identifying opportunities and barriers and advising its member organisations on actions needed to achieve an optimum outcome.

2.7 TSAG will direct the work of the System Interface Committees and work closely with other related cross-industry groups, ensuring that their agendas are consistent with long-term needs, as well as encouraging efficiency in the means by which these are developed and adopted. RSSB has the responsibility for establishing the formation of the group and facilitating regular meetings.

2.8 TSAG will also own the agenda for strategic research. Many research initiatives are already in hand, driven through RSSB, Network Rail and ATOC. The benefits of academic involvement should continue to be exploited, principally through Rail Research UK, and maximum value extracted from European research co-operation. Professional bodies can also help. The engineering institutions are already facilitating a number of seminars on key aspects of the RTS and the work of the System Interface Committees.

Scope

2.9 The scope of the RTS covers the 'heavy rail' system in Great Britain, encompassing the railway infrastructure owned by Network Rail and the passenger rolling stock owned by RoSCos and train operators, complete with the people and processes that make the railway run. The RTS will therefore need to be taken forward in conjunction with the devolved administrations.

2.10 A 30-year time horizon has been adopted, both for consistency with the 2007 Rail White Paper and because this is a reasonable average figure for railway asset life, which ranges from electronic equipment at 5–15 years through rolling stock and track at 25–40 years to stations and structures at 40–120 years.

2.11 The RTS develops a long-term view of the future railway system, assesses the extent to which this future is likely to be realised through 'natural' incremental change mechanisms in response to current incentives and highlights areas where planned strategic changes and changes to incentives are needed. It is intended to be a living document responding to future technology development and the results of ongoing research.

3. Needs and requirements

Strategic drivers

3.1 A best forecast of the needs that the railway will have to meet over the next 30 years is set out in the 2007 Rail White Paper. These needs are driven primarily by economic, societal and environmental change. They inevitably involve a high degree of uncertainty, but, in planning for a transport system that involves major capital expenditure on long-life assets, future needs must be predicted and anticipated using the best available data and tools.

3.2 The most challenging scenario for the railway is to assume high economic growth (and therefore high growth in passenger as well as freight demand and more demanding customers) coupled with, first, a high level of environmental concern, tending to drive change towards minimum carbon emission (high energy efficiency) and, second, a need for high cost-effectiveness in terms of capacity per unit expenditure so that the nation can afford more railway services.

3.3 In responding to these demands, a balance must be maintained between the need to drive costs and carbon emissions down and capacity up, whilst maintaining open access across the network, particularly for freight.

3.4 The key drivers that require the railway system to develop and change in a fundamental way are those elaborated in the 2007 Rail White Paper.

Capacity

3.5 Whether or not new railway construction is ultimately justified, the railway must make best use of the infrastructure corridors that it has inherited. Current forecasts suggest that, by the 2020s, on key main lines and the approaches to major cities, passenger demand will increase beyond the scope of relatively easy incremental changes such as train lengthening, peak spreading, or minor local layout and signalling modifications. Significant freight growth is also expected, particularly to serve container traffic to and from ports.

3.6 Further incremental changes, such as grade separation at junctions and additional platforms at stations, can provide significant further enhancement to capacity, but these get progressively more costly, and land availability makes additional surface running lines in urban areas prohibitively expensive in most cases.

3.7 At this point, radical change to the railway system may become both necessary and cost-effective. At 125 mph with 3-minute planning headways, which is approximately the figure on the recently upgraded West Coast Main Line, trains are more than 6 miles apart, or about three times the minimum service braking distance. A railway with highly reliable component parts operating a precisely controlled service and using communications-based cab signalling to eliminate train performance and signal sighting compromises should be able to offer line capacity nearer to the limits of steel-wheel-on-steel-rail technology while maintaining safety standards.

3.8 Availability of the network 24 hours per day, 7 days per week will also be a key issue in meeting capacity requirements, for instance by allowing more freight to operate overnight without disruption from engineering possessions.

Carbon, emissions and the environment

3.9 The railway is correctly perceived as an environmentally-efficient form of transport, but the need to keep ahead of competitors and make a significant contribution to wider environmental targets will put pressure on the railway to substantially improve its energy efficiency and overall environmental footprint. Short-term measures to reduce carbon emissions, such as intelligent control of lighting, reduced idling, and driver training, under the control of individual operators, can deliver substantial benefits but will rapidly reach their limits. Further substantial improvement can be delivered by initiatives using not only currently-available technologies such as energy metering, regenerative braking and lighter trains, but also emerging technologies, such as hybrid drives and predictive control of train movement linked to driver advisory speeds.

3.10 Reduction in net carbon emissions can also be achieved by changing fuels and energy source. There are no significant technical barriers to the use of biofuels. Hydrogen is a longer-term possibility. Both depend on availability of a truly renewable source. Electrification is a mature and available technology and is an efficient way of transferring energy from power station to train, but its high capital cost competes with other spending priorities; it also increases the complexity and vulnerability of the network. Further, a decision to electrify the whole network now would be vulnerable in the long term to development of a renewable source of portable energy.

3.11 Other environmental issues also need to be considered, and these are likely to become increasingly important over time. The railway will come under growing pressure through the Environmental Noise Directive to reduce its noise emissions and is already under pressure to reduce its impact on local air quality through the Non-Road Mobile Machinery Regulations. The appropriate solutions need to be selected in response and applied in a rational way.

Customer expectations

3.12 Customer needs and expectations will change substantially over a 30-year period. The average passenger will be more affluent, taller, wider and older than now. For both passengers and freight, what is accepted now in terms of service quality is unlikely to be acceptable in 30 years' time. Competition from road transport will change, particularly if there is greater automation or road transport's average speed falls in response to energy considerations. Consequently, rail will need to deliver higher levels of reliability, comfort, accessibility and information. This will be a particular challenge in the context of increasing demand, because reliability and comfort naturally tend to fall as usage of the network increases. Additional train capacity and better service performance will be key, but the coherent use of technology to deliver information on train status and loading in real time will not only improve utilisation, but also offer seamless planning as well as accurate information on availability of freight and passenger services and seating capacity. Passengers might expect a text message on or before arrival at the station, telling them where there are empty seats on their selected train.

3.13 Accessibility needs must be addressed in both train and station design, but in a balanced and planned way to deliver the best outcome for all. Significant progress has been made in making it easier for those passengers who have an impairment (whether that involves a disability, parents with small children or travellers with luggage) to travel by train. The introduction of the Technical Specification for Interoperability (TSI) for Persons with Reduced Mobility will bring these benefits to many in Europe, whilst also controlling costs in the UK by replacing expensive bespoke solutions.

3.14 An ageing population, with greater aspirations for travelling, means that the rail industry must continue to make access improvements if it is to attract this increasingly important market. And measures to improve access can benefit all travellers, including those with impairments such as hearing and sight, or those facing language barriers – whether they are on-train passenger information systems or improved way-finding at stations.

3.15 The national rail fleet will continue to become more accessible, as new stock is procured and older vehicles are refurbished. The rail industry will target work at those fleets that can be brought up to an acceptable standard, and plan for the replacement of those that cannot.

3.16 Innovative solutions that deliver improved access alongside improved capacity, with reduced dwell times and weight, need to be developed.

Safety, security and health

3.17 Pressure to maintain the position of railways as a relatively safe form of transport will continue as societal pressures change, the value of life increases in response to greater wealth, and competing modes get safer. In particular, developments in road transport safety systems may support cars maintaining the substantial edge in terms of security and perceived health risk. Technology can help, both by addressing specific issues, such as level-crossing risk, and by making existing safety systems cheaper and more effective. However, from a passenger point of view, safety, security and health are all aspects of travel risk, and the major challenge to railways is likely to come from the security viewpoint. Here, technology will be key, and systems such as automatic behaviour recognition and automatic scanning for explosives and weapons may become commonplace. In response to tightening of security, passengers may be offered choice in terms of the degree of pre-clearance they are prepared to undergo in return for faster access to the system, as is already happening with air travel. To address the health issue, railways in some parts of the world are already installing improved filters on air conditioning systems and anti-viral coatings on handrails.

Cost efficiency

3.18 There has been significant capital expenditure over the last 15 years, with major elements of this being enhancements and new rolling stock. Operating costs have also increased in absolute terms over the same period, but real operating costs per train kilometre are only 2% lower than 10 years ago, despite significant improvements in the quality of the rail product. Pressure on cost-effectiveness can be expected to continue to the end of the current planning horizon and beyond. Efficiency improvement will continue to be the major driver for cost reduction, particularly in the infrastructure area, but technological and operational change will be expected to make an increasing contribution. Designing for reduced maintenance through appropriate differentiation of standards and solutions for the varying needs of different railway sectors will be key. Solutions will need to be driven by whole-life, whole-system cost, but with affordability constraints and innovative funding mechanisms built into implementation planning, as is already being done for the European Rail Traffic Management System (ERTMS).

European legislation

3.19 Over the next five to ten years, European railway interoperability, safety legislation and technical standards will be completed and enacted through UK regulations. Although this process contains some risks, the UK view can influence development and revision of standards to ensure a ‘good fit’ with business objectives and needs. The 30-year industry view can and should be used to drive both the UK’s response to emerging standards and the scope and degree of compliance adopted, where choice and flexibility exist. It will also need to recognise the UK’s obligations under the terms of the European directives governing open access.

Future traffic types

Passenger

3.20 The range of passenger traffic types encountered over the 30-year period will be little changed from now:

- Very high speed (250 km/h or over), currently only the Channel Tunnel Rail Link (HS1);
- High speed (up to 200 to 225 km/h) with stops at intervals of around 40 to 100 km, providing high standards of comfort and on-board amenities;

- Interurban, covering both medium-distance travel between regional centres and London area outer-suburban services, with a top speed of 160 km/h and stops at intervals of around 5 to 40 km, providing some on-board amenities and with the objective of providing seats for all passengers;
- Outer/inner suburban, dominated by short-distance commuter traffic. The key issue is passenger capacity, with standing accepted as inevitable on short journeys, and minimal on-board amenities. Speeds are relatively low, typically not exceeding 160 km/h, with frequent stops at intervals between 1 and 5 km apart. This type of operation may largely be found in the London area, but has parallels in other major conurbations;
- Regional, encompassing rural cross-country and branch lines, and characterised by relatively sparse services and low speeds, probably no higher than 160 km/h, and with stops at intervals of 5 to 20 km;
- Community, similar to regional services, but identified as having specific local significance, possibly with shorter overall journeys, lower speeds and more frequent stops to capture the maximum possible business.

3.21 Although the traffic types may not change, the pattern of travel by time of day may do so. There are already strong signs of demand for 'round the clock' travel in urban areas and, if this continues, there will be profound implications for maintenance strategies.

3.22 Although theoretical divisions between traffic types can be made, passengers will get on whichever train arrives first and offers a reasonable journey time. Many commuting services are provided opportunistically by whichever high-speed, inter-urban or regional service happens to serve the origin and destination in question at the appropriate time. This can lead to demand, over short distances and within limited time periods, that is radically out of proportion to loadings over the day and over a whole route. More flexibility in terms of both train operation, with more en-route coupling and uncoupling of units, and fares structure, to incentivise use of slower local services, may be needed.

Freight

3.23 The rail freight market is defined by the key commodities that are moved. The following freight traffic types are expected and – again – will be little changed from now:

- Non-bulk long-distance freight servicing a variety of markets, including intermodal flows carrying international containerised trade or its domestic equivalent, as well as 'conventional' rail wagons carrying commodities including automotive components and products, and non-time-critical domestic retail distribution. These services operate at average speeds of around 120 km/h, thus keeping up with interurban passenger services, and have tended to get longer to improve utilisation of freight pathways, locomotives and staff. They can benefit from train lengthening and gauge enhancement – especially on routes used by containerised flows. Given the expected doubling of port container throughput over the next 30 years, this is expected to increase at least in proportion as a type of freight traffic. A considerable increase in international traffic is also expected, with specific implications for gauge.

- Bulk freight – covering business areas such as coal, aggregates, steel, oil and chemicals, and characterised by high volumes and axle loads but relatively low speeds (up to 100 km/h). Trains of this kind operate currently with up to 25.5 tonne axle loads on key trunk routes between ports, main concentrations of power stations, quarries, railway maintenance depots and urban centres, and can benefit from train length enhancement. Some freight operators wish to increase axle loads up to 35 tonnes. Some freight operators are also beginning to consider the costs and benefits of track-friendly bogies as a means of minimising impact on infrastructure while also maintaining or even improving line speeds.
- Network Rail track maintenance freight – associated with maintenance of the rail network, both for delivery of materials such as ballast and rails from their sources, which mirrors many of the requirements of bulk freight, and for ultimate delivery from stockpiles to worksites by engineering trains. Such trains can and do operate anywhere on the GB rail network.

3.24 Possible new and expanding niche markets are:

- Express/distributive freight – regular high-value time-critical business such as retail distribution, parts, parcel and mail, using trains with performance and physical characteristics comparable to passenger services, operating largely between major centres and so tending to use main lines. This is currently a niche market but could expand in the long term if relative costs change between rail and road. Opportunities for use of rail facilities for retail distribution could be exploited.

3.25 Path take-up for freight services varies according to the characteristics of the market served. Intermodal services run consistently to planned schedules between fixed origins and destinations in a similar manner to their passenger equivalents, as do many other non-bulk services. Bulk commodities tend to operate between fixed locations, but with significant variation in take-up of paths, depending upon customer requirements. Aggregates traffic, although originating at fixed locations, may also vary in its delivery terminal. Many new flows need to start under short-term planning arrangements, and some traffic flows are inherently of an irregular nature, such as delivery to construction projects. Path take-up is heavily influenced by the need to have duplicate paths to avoid engineering possessions and to accommodate short-notice possessions. Better predictability of possessions and diversionary routes would improve freight path take-up. Unlike passenger trains, for most commodities, if there is little or no demand for a particular booked service on a particular day, the service is cancelled and does not run. One of the key needs for freight is therefore a better method of creating and validating short-term train paths by dynamic rescheduling of the timetable.

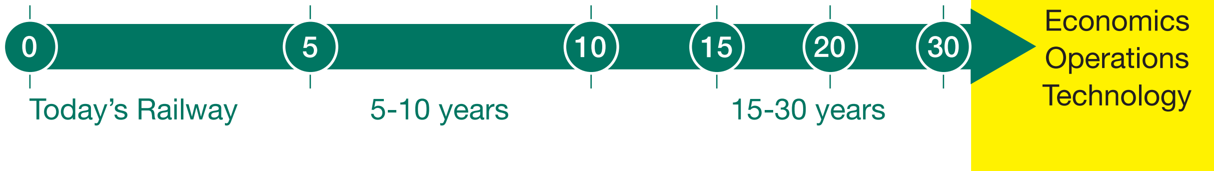
4. The future railway as a system

Characteristics

Figure 4.1: **Characteristics of the future railway**

Characteristics

- Optimised track–train interface
- High reliability, high capacity
- Simple, flexible, precise control system
- Optimised traction power and energy
- Integrated safety, security and health
- Improved passenger focus
- Rationalisation and standardisation of assets
- Differentiated technical principles and standards



4.1 Figure 4.1 shows the characteristics of the future railway as a system established in this document:

- **Optimised track–train interface:** Light, but strong rolling stock running on precisely-engineered, accurately-maintained track, reducing energy demand, track maintenance cost and noise;
- **High reliability, high capacity:** Infrastructure designed on lean principles with minimal trackside equipment to minimise scope for critical failures, with monitoring of components that may result in critical failures, so that maintenance is focused where it needs to be and faults are detected before they affect service operation, and also promoting availability of the network by minimising possession requirements;
- **Simple, flexible, precise control system:** Cab signalling combined with an intelligent management layer to reduce equipment costs, combined with an intelligent management layer to offer precise control of train movement through the network, reducing unnecessary stops, facilitating energy efficiency through advisory speeds and allowing its full potential capacity to be realised;
- **Optimised traction power and energy:** Regenerative braking on all trains, whether on the electric network or through hybrids with onboard energy storage. Better use of existing electrification and selective extension where justified by business need. Bi-mode trains capable of running on or off-wire, based on energy storage and with onboard power only where needed;

- **Integrated safety, security and health:** Bringing together automated detection of abnormal behaviour in public areas with better protection of railway operational areas from intrusion and obstruction whilst continuing to improve safety of the railway system through improvements to control;
- **Improved passenger focus:** Exploitation of ticketing, passenger flow, train movement and train load data to give high-quality information to passengers throughout their journey, highlighting lowest-cost options, available passenger capacity, alternative services, routes and modes and options for journey completion, including bus, taxi and bicycle. Use of the same data to optimise controller response to abnormal traffic or passenger flow conditions;
- **Rationalisation and standardisation of assets:** A rationalised approach to asset specification, with greater use of modular and 'commercial off the shelf' (COTS) equipment for industry-specific assets such as rolling stock, based on a whole-life, whole-system cost approach across all industry partners;
- **Differentiated technical principles and standards:** Application of differentiated technical principles and standards to railway routes based on predicted traffic type and usage, allowing cost-efficiency to be optimised whilst maintaining interoperability for passenger trains and access for commercial freight to all areas of the network, except where it is agreed that there is no reasonable expectation of future need.

Filling in the picture

Optimising the track–train interface

4.2 The RTS is based on an assumption that 'steel-wheel-on-steel-rail' technology will remain in use for the foreseeable future, for high-speed and mass public transport as well as for freight.

4.3 The need to minimise energy use and track damage, and therefore train mass, will be a major focus of new train design. The introduction of the Intercity Express Programme (IEP) between 2012 and 2020, will lead the application of 'best in class' train design coupled with improvements in track tolerances to reduce train mass significantly, reversing the recent tendency to increase mass per seat. Lighter, highly reliable passenger rolling stock will reduce energy demand and track maintenance cost, as demonstrated by the Vehicle–Track Infrastructure Strategic Model (VTISM) sponsored by the Vehicle–Track System Interface Committee.

4.4 Key changes will be:

- The use of best-practice design to deliver trains with substantially lower mass without compromising safety, combining light body shells, like that of the Pendolino, with light bogies, like those of the Voyager, and with interior equipment and furnishings designed within an overall weight target;

- Precisely-engineered, accurately-maintained track, facilitating the development of lighter trains that cause less track damage and reduce maintenance cost, thus creating a virtuous circle;
- Intelligent infrastructure, monitoring its own health and using on-train monitoring so that faults are detected before they affect service operation and help to ensure maintenance is focused where it is needed. The designers of new infrastructure will need to analyse potential failure modes and design-in protection against such failures or, where this is not practical, a process of gradual degradation of service rather than absolute failure;
- Track alignments will need to be maintained to tighter tolerances to achieve the attainable benefits at the track–train interface. The surface damage and wear of rails and wheels can be reduced through a careful balance between track quality, curve radius and cant deficiency on the one hand and wheel profile, conicity and primary yaw stiffness of the vehicle bogie on the other. Sustainable operational limits will be needed for track alignment deviations and wheel wear, driven by system whole-life cost rather than by the much less stringent needs of safety.
- Accurately maintained track to the design alignment will be required to ensure optimum clearances to over-line and platform structures. The need to carry payloads such as 9’ 6” containers will necessitate maintenance of adequate clearances to older structures, which are often at a lesser gauge than their modern equivalents. The maintenance of better precision and control of alignment will facilitate the development of sustainable operational limits for the railway, ensuring that best use is made of corridor space and that line speeds are made more consistent.

High reliability, high capacity

Developing the present system – ‘reconfiguring’

4.5 Increasing utilisation of existing capacity is a very important theme before increasing the capacity of the system. The systems and incentives need to be put in place to make better use of assets, so that we encourage existing customers to modify their usage of the railway towards quiet, off-peak periods when there are empty seats, empty wagons and even spare train paths available. Peak spreading and better information can help passengers. Better predictability can help freight path take-up. However, these initiatives will always have limits.

4.6 Increasing the capacity of the system to carry passengers or freight implies one or more of:

- Increasing passenger capacity or freight payload per unit length of train;
- Increasing the length of trains;
- Increasing the number of trains on the network.

4.7 Accommodating growth in passenger numbers whilst making a start towards easing overcrowding will be a significant feature of the first HLOS. However, that approach will soon reach its practicable and acceptable limits. Thereafter, double-deck vehicles remain an option, but recent work suggests that lengthening of trains beyond the current 12-car conventional maximum is likely to be cheaper and provide greater benefits than double-deck trains, despite major costs incurred to extend platforms.

4.8 For freight, the major thrust in recent years has been to increase gauge, allowing larger containers and greater bulk to be transported, and this trend will continue. Increasing payload per unit length implies heavier axle-loads, and for bulk commodities such as aggregates on specific routes this is likely to be an economic way of increasing capacity. For most commodities it is likely that lengthening of trains will prove more cost-effective. However, this may require some investment in extended loops, new accommodation and road bridges, and terminals.

4.9 Increasing the number of trains on the network may require upgrades at several locations along a route before significant benefits are delivered.

Radical change to the network – ‘re-engineering’

4.10 New signalling systems such as ERTMS can improve the potential frequency on individual lines within the network. The ultimate effect will depend upon the characteristics of each route, and particularly what other capacity constraints are encountered. Key junctions, terminal capabilities, and the mix of train speeds all have a role to play, but a ‘clean sheet of paper’ approach to revising the Rules of the Plan will be triggered and should also support the removal of differentiated speeds for freight trains.

4.11 Potential increases in line capacity of up to 20% have been claimed for ERTMS. The route between Berne and Olten in Switzerland is signalled with ERTMS Level 2 (System D) and achieves a 90-second technical headway, translated into a 2-minute planning headway. Network Rail is undertaking work to better understand how this potential will apply to more traditional mixed-traffic routes.

4.12 Driver advisory speeds, improved platform departure times, backed by predictive routing algorithms and supporting regulation of train movements through junctions, can ensure presentation of trains ‘just in time’ to utilise a free path, rather than stopping and starting from rest when a path becomes available. This will be particularly important where the network is used by freight trains (and to a lesser extent high-speed passenger trains) with low acceleration and requiring a significant time simply to release the train brakes to restart.

Network performance and availability

4.13 Network performance may be improved by reducing the likelihood and impact of primary delay. Reliance on high-reliability equipment will benefit service performance by reduction in likelihood of primary delay. Work on intelligent, flexible operating rules and efficient operations management may also be of benefit in minimising the impact as well as supporting provision of additional capacity. This may allow 'buffer' capacity to be brought into productive use without increasing overall delay. However, running additional trains in itself presents a greater exposure to secondary delay in the event of any disruption.

4.14 High reliability of rolling stock will be essential. Figures of 100,000 miles between service-interrupting failures (between 2 and 4 times the current UK level) are already achieved elsewhere. Reliability will be promoted by an approach based on harmonisation of basic elements, standardisation of interfaces and evolution of proven components around a modular concept, such as that being pursued by the European MODTRAIN project.

4.15 Track maintenance will be planned on a 'predict and prevent' basis, based on monitoring assets by train-borne equipment, and use of 'intelligent infrastructure' noting trends and rates of deterioration and making planned interventions *before* an asset fails. Access to near-real-time asset status information will allow predictive maintenance to be a reality, greatly reducing network downtime and avoiding premature renewals.

4.16 Network Rail is assembling a comprehensive database of information associated with their infrastructure assets and records of its conditions. The data will be available to the asset engineers to assist determinations of deterioration rates and thus maintenance needs. This knowledge bank is populated with the core asset data and data received from track recording trains as well as track-based recording sensors monitoring trains.

24/7 railway

4.17 Availability of the network 24 hours a day and 7 days a week (24/7) will be enabled by current and future technology. High-output systems for renewals and ballast-cleaning allow work to be undertaken on a single line with the adjacent line open to traffic under bi-directional working arrangements. Planning around suitable diversionary routes (with equivalent freight capabilities) will be promoted where possible. In the longer term, alternative track formations such as slab track will minimise maintenance needs, especially on critical sections without diversionary routes or where traffic requirements too intensive for single line working have to be accommodated.

4.18 New systems, procedures and equipment will be required to provide a 24/7 railways as the norm. This will be achieved through maintenance and renewals being undertaken when the network is more lightly used and reduced capacity would be acceptable. The number of trains, including passenger, empty stock and freight trains, is much reduced in the late evening through to the early morning, a period of 5–8 hours. In this period, the train timetable will be planned to use half the normally available infrastructure, such as two tracks of a four-track section or single line working on a two-track section. On a four-track section, the reduction to two tracks will halve the capacity, subject to the arrangement of lines and their relationship to platforms where the passenger services normally stop. On two-track sections, the capacity will be much less than half and the open line will be working bi-directionally.

4.19 Possessions will need to be taken and given up in 10–15 minutes to give time for significant units of work to be completed in an 8-hour period. Normal maintenance operations, such as tamping, rail grinding, rail stressing and defect removal, can be undertaken with adjacent lines open. Renewals, however, have always been more problematic. The new high-output track renewals system and ballast cleaners can and do work with adjacent lines open – however, traditional renewals have required a second line for rail cranes. Factory-assembled modular switch and crossing units with pre-commissioned signalling equipment will be installed or replaced within an 8-hour possession.

4.20 These systems, work practices and infrastructure designs will enable extension of the maintenance and renewal of infrastructure that can be undertaken with trains running alongside work sites, particularly on two-track sections, and all within 8-hour possessions.

4.21 This higher level of availability will be needed despite the additional stress placed on the network through climate change. Higher temperature ranges will require more frequent rail stressing, and more frequent and more intense storms will find weaknesses in drainage and vulnerabilities to embankment slip, bridge scour and wind, particularly for overhead electrified lines.

Operational planning

4.22 Traditionally, the railway has relied on knowledge of the network in its incremental approach to the development of timetables. Capacity is determined by experience-based 'Rules of the Plan', which set pragmatic headways and junction margins. When major changes are being carried out, analysis of capacity is made at the scheme design stage, but this is usually related to the changed area only. To maximise the use of latent capacity in the network, a fully integrated approach is needed.

4.23 Network Rail is developing a detailed data model of the infrastructure, which will support both engineering change management and operational planning, together with an approach to timetabling based on analysis of train and infrastructure capability using margins set within a 'bottom-up' model. The model will reflect train and infrastructure reliability as well as operational capability. Such a model will also support fast analysis of short-term timetable changes.

Simple, flexible, precise control system

4.24 The current railway control system is complex, has a high infrastructure equipment count, is expensive to maintain and exposes maintenance workers to trackside risks. It is focused on maintaining safe train separation, with little in the way of a system management layer, and is imprecise and hugely variable in terms of the precision of train tracking through the network.

4.25 The vision for the future is a system in which intelligent trains each send their own location, derived through data fusion combining satellite positioning data with odometry and balise information, back to a small number of control centres. These will control safety-critical train separation through movement authorities and manage train regulation through driver advisory speeds or timings to minimise delay and save energy. Track-based train detection will be eliminated, except at key nodes and junctions, where axle-counter detection will facilitate rapid clearance and degraded-mode operations. The (imperfect and opportunistic) ability of the conventional track circuit to detect rail breaks should migrate to infrastructure systems designed for the purpose. Overall, a simple, flexible system will:

- Improve safety, through provision of Automatic Train Protection and reduction in risk to trackside workers;
- Enhance capacity, by decoupling signalling layout from train performance and signal sighting constraints, thus reducing line headways and junction occupation times, with support for Automatic Train Operation where needed for operational reasons;
- Improve service performance, through elimination of primary delay arising from failures in line-side signalling equipment, and through 'gradual degradation' in partial failure conditions;
- Reduce costs, through reduction in the quantity of equipment to be installed and maintained;
- Provide bi-directional signalling as standard to improve flexibility in the event of disruption;
- Facilitate simpler and more optimal electrification schemes by removing signal sighting constraints.

4.26 GSM-R will be the operational radio system initially, but this will develop through GPRS to a high-speed operational data-transmission system, working bi-directionally with high availability between train and track.

4.27 Following several years of economic and technical analysis by a cross-industry programme team, ERTMS Level 2 has been selected by Network Rail as the default system for re-signalling in the medium term. Currently the pilot ERTMS project is in the course of implementation.

4.28 Future communication-based cab signalling will build on the original ERTMS concept, including both safety and traffic management layers and incorporating satellite-based tracking into the architecture, allowing track-based train detection to be eliminated. Virtually all trains will be fitted with the system unless clearly operating only in yards or on dedicated freight or community lines.

Optimised use of energy

4.29 The right long-term solution for rail is one that minimises its carbon footprint and energy bill. Fundamentally that depends on the relative rate at which the carbon footprint of electricity generation declines and the rate at which options become available for low-carbon self-powered trains, neither of which can be forecast at present.

4.30 Energy efficiency has already acquired a much-increased importance for both cost and environmental reasons, and this will continue. Regenerative braking will be universal on electrified railways and will be incorporated into self-powered trains through the use of hybrid technology. Both electric and diesel trains will have on-board energy metering and management systems. An efficient train regulation system will manage the movement of trains through the network, providing advisory speeds to drivers to minimise unnecessary stops. Automatic Train Operation (ATO) will be used in areas where precision and consistency of propulsion and brake control are crucial to achieving high capacity; it can also be used to optimise energy consumption.

4.31 Currently, from a carbon emissions point of view, electrification seems attractive and may become more so as net carbon emissions from electricity generation decline. Electrification can have a capacity benefit on high-performance trains where a diesel power car is replaced by passenger accommodation, and this benefit is likely to apply to less powerful trains as emission regulations get tighter and under-floor diesel installations get more difficult. There are also operational cost benefits from running electric trains compared to diesels. However, electrification is expensive, and a national electrification strategy committed now would divert funds away from more pressing capacity improvements. Further, alternative energy forms of railway traction may advance. If the problem of a renewable supply of hydrogen is overcome by bioengineering, for example, the environmental economics might be transformed. The course to be pursued thus needs to balance the environmental and other benefits of electrification against funds available and the progress of alternatives.

4.32 The internal combustion engine is likely to remain the major non-electric power source on rail vehicles for the next 10 to 15 years, but changes in fuel are likely. In the short term, a switch to low-sulphur gas oil or diesel will be needed to allow exhaust-after-treatment technology to work effectively and comply with emerging European legislation. Biofuels are already a feasible option and their use, mixed with fossil fuel, is likely to become widespread very quickly, as is happening already for road vehicles. The rate of take-up will be limited by the sustainability of supply rather than by technology. A switch to other liquid fuels such as methanol is possible.

4.33 A high level of attention is being applied worldwide to the hydrogen fuel cell, and traction packages at the power density needed for light trains are already feasible. Cell life and cost appear likely to reach levels that would be acceptable for rail within the next ten years. However, a hydrogen-fuelled railway deriving its primary energy from electricity or fossil fuel would be unable to compete on carbon footprint with an electric railway, except perhaps for rural lines, so widespread use of hydrogen for rail would depend on a truly renewable source of hydrogen, such as photosynthetic splitting of water using bioengineered algae. This has already been demonstrated on a laboratory scale.

4.34 All vehicles that have a primary energy source will be hybrid, as without this they will not be able to regenerate and will therefore have a fundamental energy penalty. It is expected that, within the next five to ten years, production trains using hybrid power will be in regular fleet service.

4.35 New electrification, except minor infills within the third-rail network, will use the 25 kV Overhead Electrification (OLE) system consistent with the Energy TSIs, with distribution operating at 50 kV through auto-transformers. In the areas where it is fitted, the third-rail system is likely to stay, as replacement with OLE costs as much as initial electrification, and electrification of unfitted areas should get first priority when funds become available. Although third rail represents a higher level of hazard to railway staff, the evidence is that the risk may be mitigated. For OLE systems, the operating consequences of damage to the overhead conductor are such that future designs should be more robust.

4.36 Many trains will be capable of 'bi-mode' operation, drawing electricity from the wires where available but running on portable fuel where not. Battery technology will have advanced and may be capable of supporting rural services in combination with discontinuous electrification, avoiding the infrastructure costs associated with electrification in tunnels and in complex areas.

4.37 The need to minimise energy use through reduced train mass will be a major focus of train design. Over the next thirty years, improvements in track tolerances and protection standards will have enabled train mass to be reduced significantly, offsetting the increase in mass per seat that occurred in the late twentieth century in response to the pressure for greater crashworthiness, accessibility and additional passenger facilities. A target of 356 tonnes for a 260-metre Intercity Express train has been set in the draft functional specification, which represents a reduction in mass per seat of approximately 40% over existing train designs. Work by the IEP team suggests that this target can be achieved without compromising crashworthiness or accessibility by combining UK best-practice elements of current train mechanical and structural design and eliminating such things as the very large amount of additional cabling carried by UK trains in comparison with modern trains elsewhere in the world. Intelligent control systems will manage auxiliary demands and idling.

An integrated view of safety and security

4.38 The track record of the rail mode in terms of safety is good. Despite extensive publicity of accidents, the risk of death or injury from a railway accident is not a major concern for most passengers. Given current trends, personal security in the face of crime and terrorism is likely to be perceived as much more of an issue by passengers in the future and, when passengers decide whether or not to go by train, they see safety and security as aspects of safe travel. The issues of safety and security are therefore treated together in the RTS.

4.39 Most major safety risks now arise externally to the rail network – level crossings, vandalism, bridge strikes – and these can be expected to be addressed progressively.

4.40 The safety balance will change in the period of the RTS:

- Full automatic train protection will be an inherent component of the new control system, which will have been deployed across most of the network;
- Level crossings will be reduced in number and better protected using CCTV or radar-based obstacle detection, coupled with direct communication with the train, so that train speed can be reduced to a level at which collision with a road vehicle is very unlikely to cause derailment. On the highway side, stricter enforcement coupled with measures such as central dividers at half-barrier crossings should improve compliance;
- Detection of infrastructure failures through measures such as condition-monitoring by fixed equipment or trains carrying measurement equipment will be extensively adopted for economic as well as safety reasons;
- Better redundancy and fallback modes will reduce dependence on the 'fail-safe' principle, which in practice leads to continued operation under manual control and without support of safety systems;
- Error rates and human failures during both train and infrastructure maintenance will be reduced through better testing and better quality control.

4.41 Security will be an integral aspect of railway systems, even those not having a safety-critical prime function:

- Access control through continued use of gating on stations will be extended;
- Scanning for passenger numbers and weapons remains an option, although the risk needs to be balanced against the disadvantages in terms of capacity;
- Closed-circuit television (CCTV) will continue to be developed, including automatic face recognition and detection of abnormal behaviour;
- Open train interiors, promoting better visibility of passenger activity;
- External TV and sensors may be employed on trains to detect intrusion.

4.42 Concern over public health will be a major issue for public transport, implying demand for:

- Better air conditioning with active filtration of recycled air;
- Anti-bacterial and anti-viral coatings;
- Elimination of uncontrolled-emission toilets.

Improved passenger focus

4.43 Although major investment in trains has benefited passengers directly in terms of comfort, cleanliness and reliability, the same level of attention has yet to be paid to passenger information in its widest sense or to stations. Smart ticketing systems are already being rolled out and will rapidly become more integrated with both passenger information and financial systems, initially through the use of mobile phones fitted with Near Field Communications.

4.44 It is impossible to predict 30 years ahead the exact means by which information will be delivered to passengers, but it is clear that, long before this, the customer-facing service will be based on precise and up-to-date information on train location and loading as well as infrastructure and train status held in a linked family of datasets. These may be held by the operators, Association of Train Operating Companies (ATOC) and Network Rail or an information brokering service. Collection of data from passenger-count systems will also support better response in real time to incidents and disruption, based on accurate knowledge of the number and destination of passengers involved. The same information collated and analysed will improve understanding of current travel patterns and market behaviour, leading to improved availability of management information for both short-term planning and forecasting to support long-term appraisals and strategy formation.

4.45 The passenger railway will need to support sophisticated and advanced facilities for creating a seamless journey experience from planning through ticketing to information at stations and on board, then to post-journey feedback.

4.46 Satellite communications will feature widely in the railway of the future, providing the basis of systems for accurate positioning of trains for both safety control and management. Individual vehicles and passenger loads will be tracked to provide a capability for load management. Satellite technology may also facilitate vastly improved data and voice communications for passengers on trains and stations, with properly integrated auxiliary systems covering areas where the sky is obscured. The ability to interact with the outside world during a journey and use travelling time productively is an increasing source of competitive advantage for the rail mode, which should not be lost.

4.47 Passengers will expect to spend less time on stations as reliability of the system and connections improve, but station design will be expected to deliver consistent standards of accessibility and interchange, as well as passenger support, and contribute to enhance security. The integration of retail facilities may change along the lines already adopted in Holland, where one person in a semi-protected environment sells tickets, operates a retail store and carries out first-level security supervision.

Assets and cost

4.48 The general pressures to improve availability of assets and reduce their whole-life costs will continue, aimed at maximising availability as a 24/7 railway. Direct pressure on costs through infrastructure cost-efficiency targets and competition for franchising will continue for the whole of the period and beyond, but the rate of return will start to fall off as the soft targets are taken up. Care needs to be taken in regulating this situation to avoid both damaging innovation and creating perverse long-term consequences. Delivery of many of the changes outlined in this document will require partnership between train and infrastructure owners and operators, eliminating some of the drivers of high cost, particularly in terms of complexity, lack of standardisation of trains and infrastructure, combined with better optimisation of the railway for its actual use.

4.49 The development of a rational set of standardised solutions, each optimised for its sector, is a critical part of the future railway system.

Rationalisation/standardisation

Passenger rolling stock

4.50 There will be a rational 'family' of train concepts for specific needs, facilitated by Government, adopted by the industry and setting high-level requirements for gauge, mass, passenger capacity, performance, accessibility, couplings and interoperability. The development of standard solutions at modular level (for example body shells, traction packages) is being addressed through European research:

- **InterCity (IC):** Trains travelling several hundred kilometres at speeds of up to 225 km/h with a typical journey time of 3 hours and stopping intervals of 30 minutes or more. Trains in this category are likely to retain end doors, because seating capacity is more important than very short dwell time, but must have good low-speed performance to keep up with other traffic in congested areas. Electric, self-powered and bi-mode versions will be needed for many years to come. This need will be met primarily by the IEP, which is planned to replace the HST (High-Speed Train) and IC225;
- **Interurban:** Trains travelling around 100–200 km with maximum speed up to 200 km/h, typical journey times of 1–2 hours, stops every 30 minutes and loadings less peaked than outer urban. Typical route Trans-Pennine Express (TPE) Liverpool–Manchester–Huddersfield–Leeds–York, currently using Classes 185 or 170. Electric, self-powered and bi-mode versions will be needed for many years to come. This need could be met by extension of the IEP concept or by adapted outer suburban trains, which will be technically very similar;
- **Outer suburban:** Trains travelling around 100–200 km with maximum speed up to 160 km/h, typical journey times of about 1 hour, stops every 10 to 15 minutes and heavy peak loadings. Good acceleration will be important, and wide 1/3, 2/3 doors will be needed to minimise

dwell times. This role is filled currently by Classes 165, 166, 170, 350/60, 365, 444, 450. Self-powered and bi-mode units will be needed on some routes, but the dominant traction mode will be electric;

- **Inner suburban:** Maximum speed 110 km/h but with very high acceleration, journey distance no more than 50 miles, with stops every 5 minutes. Reduced seating, with a large clear area for of standing and access (e.g. roles filled currently by Classes 315, 455, 465 and 376). Future trains of this type will be predominantly electric, but with a continuing need for a self-powered option in the medium term. Inner and outer suburban units are the target for the 'New Generation Multiple Unit' projects being taken forward by the DfT and the rail industry. Thameslink is likely to be the initial target for the electric inner unit, with the specification for a self-powered train developed in parallel, aiming at high-energy efficiency through light weight combined with high-efficiency power units with energy storage. The 'tram–train' initiative, as detailed in the Rural section, may also have applications in some inner suburban areas;
- **Regional:** Trains travelling long distances on secondary lines with lighter loadings. Acceleration is not as important as for interurban or suburban trains, as stops are spread out and there is relatively low pressure on dwell times. End doors will continue to be acceptable, and passenger comfort will be important. Maximum speed will be 160 km/h in order to allow operation on main lines without degradation to other services. A track-friendly solution will be vital, as these trains will operate on light, low-maintenance track. Self-powered or bi-mode units will be the norm, but energy-storage technology combined with regenerative braking will improve energy efficiency. Re-engineering of current-generation regional trains to comply with accessibility and emissions standards could extend their life into the 2030s;
- **Rural:** 100 km/h maximum, acceleration not important, but power needed for steep gradients on some routes. Energy efficiency will be important, given the need to improve environmental credentials of routes with relatively low passenger loads. Good accessibility will be important for the local customers using the route; such trains often need luggage and cycle space for leisure users of the route. Low track force essential; reasonable comfort and good panoramic views. The 'tram–train' initiative being proposed by Northern and Network Rail is intended to demonstrate an appropriate technology for this niche and also has potential customer benefits in terms of offering a through service to street-running systems and relieving crowding at urban stations.

Communications systems

4.51 Developments in consumer technology have benefited the railway with reduced equipment prices and the ability for the railway to effectively share technology development in some areas, and this trend will continue. The current project for national roll-out of Global System for Mobile communications – Railways (GSM-R) is a good example, but also illustrates the slow rate of progress in implementing technological change on the railway. By the time GSM-R rollout is complete in 2012, the technology will be obsolescent in the consumer market. However, once GSM-R is complete, the industry will have secure and reliable communications with all cabs, and this can and should be used both to reduce the need for fixed communication points and to enhance flexibility of operation and signalling equipment needs, particularly on freight lines.

4.52 The Fixed Telecommunications Network currently being installed by Network Rail should meet operational needs for many years to come. Although designed initially for Network Rail's internal use, it can and should be enhanced to deliver train operating companies' operational needs as well. It will need to link to stations and is also likely to form the backbone for a short-range, low-power wireless communication system covering both line-side fixed equipment and non-vital high-capacity track-to-train data transfer.

4.53 Demands for fixed infrastructure to train communication will continue to increase, driven by operational, security and consumer needs. Satellite downlink and other means of broadband communication are in use already, and the industry's initiative to agree a framework of guidance for the use of such systems should be progressed, so that the approach does not become piecemeal. The speed of change in this area makes the future difficult to predict, but the expected general direction is that greater reliance will be placed on off-the-shelf systems rather than bespoke systems for railway applications, although as a customer the railway industry should be able to influence developments and standards to optimise transferability.

4.54 In order to exploit these developments, it will be necessary to work with the communications industry to understand how technology is changing, so that the development and migration of the rail application can be mapped.

4.55 A management challenge for the rail industry will be to work with the very short life expectation of products within the consumer markets, compared with the longer asset lives traditionally associated with equipment in a rail environment.

Infrastructure

4.56 The current initiative to standardise structure gauges, led by Network Rail through the Vehicle-Structures System Interface Committee, will continue, developing a rational basis for design for the rolling stock in each service group. The gauge will identify the infrastructure constraints on the main and diversionary routes for the service group. Those constraints that are very costly to remove will become the basis of the gauge. The IEP is being developed on the basis of the intercity gauge developed through the Vehicle–Structures System Interface Committee. Further work on the urban and regional service groups is in hand and will be used to support the New Generation Multiple Unit projects.

4.57 Freight gauges are based on the types of freight being transported. Whilst W6a gauge is applicable throughout the network for platform level and below, the needs for freight clearance above this level vary by type. Coal and mineral wagons generally fit within passenger stock gauges; swap-body, container and some international traffic do not. The aspiration is that the main freight container network will be able to pass 9'6" high cube container (W10) and – eventually – the wider European-standard 9'6" high and refrigerated containers (W12) – although there may be a need for the larger UIC gauge on selected routes.

4.58 Network Rail is developing a family of 'modular stations' for new and reconstructed stations throughout the network. Whilst the major terminal and regional stations will still need to match their particular needs, other stations will benefit from this concept. The modules will comprise pre-approved designed units that can be pre-fabricated and assembled within short access times. There will be sufficient flexibility in design to accommodate the needs of a wide range of station types and sizes with several architectural styles. It is important that both future stations and depots incorporate features such as good thermal insulation, solar or heat-pump based heating, rainwater collection and micro-power generation to act as beacons of good sustainability design.

4.59 Work overseas, particularly in Holland, has demonstrated the value of appropriate station lighting, finish colours and lack of clutter in creating a more attractive and less threatening station environment. Such an approach not only creates a better perception of security; it actually helps to deter vandalism and graffiti. These are areas that need further work in order to determine appropriate solutions for the UK.

Differentiated standards

4.60 The present fully multi-functional railway applies standards appropriate to the most demanding roles across a network much of which is in fact lightly used, both in terms of train frequency and the physical demands of those trains. Although some differentiation is allowed for within standards, particularly for track, there is a lack of a coherent framework for appropriate differentiation by type of use. Quite distinct traffic types should be catered for, each of which poses different demands. The universal application of multi-functional standards across the network may lead to deterioration and ultimately closure of lightly-used routes that cannot afford them.

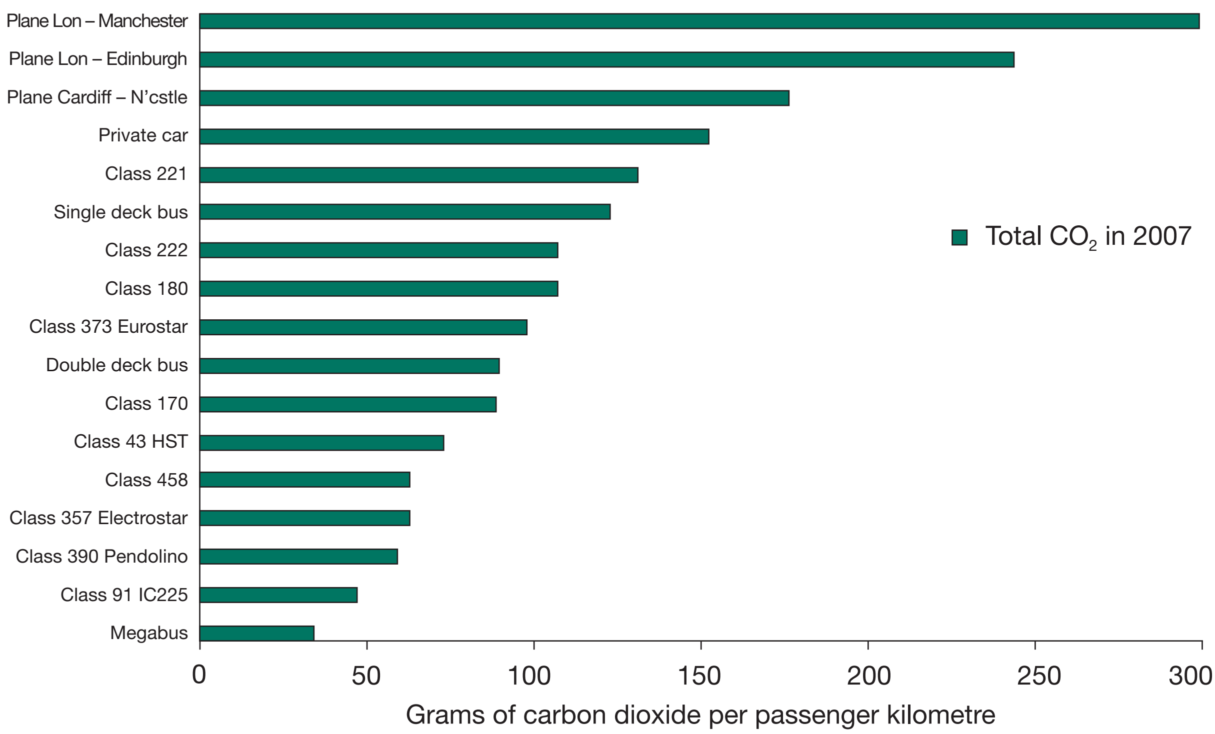
4.61 The 30-year view of the railway therefore envisages increased differentiation, allowing both infrastructure and train assets to be better optimised for their actual requirements, whilst maintaining the principle of open access across the network. Differentiation is considered a principal route to achieving improved cost-effectiveness, and further work by the industry, led by Network Rail, is being undertaken to demonstrate the benefits of better application of appropriate risk-based standards. Extending this to include a better range of gauges as a replacement to the existing 'W' series is also being promoted by industry parties.

4.62 The differentiated railway concept has been developed for the UK as part of this strategy but has also struck a chord in mainland Europe, where it is being driven forward by the European Infrastructure Managers (EIM) and Community of European Railways (CER) through the European Railways Agency (ERA). They are taking the same approach as is set out here. UK Government and industry are working together to ensure that the next generation of TSIs is based around this concept.

Environmental performance

4.63 The environmental performance of the railway relative to other modes is good, particularly in the area of carbon dioxide emissions, as shown in Figure 4.2.

Figure 4.2: **Intermodal comparison of carbon dioxide emissions**



Notes: Data assumes the following load factors: urban bus 20%, intercity coach 60%, intercity rail 40%, all other trains 30%, domestic airlines 70%, cars 30%. Road, air and diesel-powered rail vehicle emissions have been increased to take account of refinery losses and electric powered vehicles take into account losses in the grid. The aviation figures include a factor for radiative forcing.
Source: RSSB

4.64 However, further improvement will be expected to retain competitiveness as other modes improve, and the future railway will be heavily shaped by the need to reduce its impact on the environment as well as by the need to accommodate the increasing impact of climate change.

Emissions

4.65 Reduction of carbon dioxide emissions will be the highest-profile environmental issue for the foreseeable future and is treated in this

Strategy as a key strategic driver for change. Elsewhere in the document the changes to the railway system that can support this objective are laid out in detail, covering lower-mass trains, more energy-efficient propulsion and alternative fuels and energy. Over the next few years the establishment of railway industry targets within the wider UK and European framework will help to drive towards these solutions.

4.66 For other gaseous emissions, including SO_2, NOx and particulates, the diesel railway lags behind other transport modes. The implementation of the Non-Road Mobile Machinery (NRMM) Regulations is changing the situation, and, by 2012, new trains and replacement diesel engines will have to comply with criteria that are as strict as those for road. This has implications for train design, because currently it appears likely that exhaust after-treatment will be required, which will be very difficult to fit under the floor of high-power diesel trains. Hybrid traction could help, but currently the European regulations are framed in such a way that the hybrid benefits for local pollutants are not taken into account. The European Commission is currently carrying out a technical review of the regulations, while Government and industry are pressing for these issues to be considered.

4.67 Biofuels, as well as potentially reducing net carbon emissions, change the balance of local pollutants, with an increase in NOx but a reduction in particulates and SO_2.

4.68 Hydrogen fuel cells completely eliminate local pollutants because the only gas emitted is steam.

Noise

4.69 Historically, although new lines have to comply with strict planning criteria and attract objections on the grounds of noise, railway noise from existing lines has been accepted by local communities as part of the background. This is likely to change, both because expectations are changing, with widespread use of double glazing and reduction in aircraft noise, and because of the effect of the Environmental Noise Directive. The noise maps and local action plans required under the Directive are likely to change attitudes. The industry has already run into a major problem area because of train horn noise, where louder horns introduced for track-worker safety reasons have caused widespread complaints from local residents. RSSB is working with industry to find an acceptable solution to this specific problem. More generally, the response to local action plans will need to be carefully considered from a railway system level and the most appropriate and cost-effective solutions selected. So-called wheel noise, for example, is actually radiated mainly from the rails and can be reduced by rail-mounted damper units without the need for expensive and unsightly noise barriers.

Local pollution

4.70 The most pressing problem in this area is the continuing presence on a large number of trains of direct-discharge toilets, which dump human waste onto the track. Although there appears to be no evidence of actual impact on health, it is unsightly and particularly unacceptable to the public in modern stations. It is also very unpleasant for track-workers. Unfortunately, the modification of all existing trains to carry retention toilets would be very expensive and in some cases impractical. The Government is nevertheless committed to fitting controlled-emission toilets when trains are refurbished and will work with industry to find a cost-effective solution for trains with a substantial remaining working life.

Impact of climate change

4.71 Climate change can impact the railway in a number of ways, for example rail buckling arising from extreme temperatures, damage to overhead wires owing to more extreme storms, sudden earthworks failure and scour at base of bridges arising from more intense downpours, reduced summer rain leading to subsidence, storm and sea surges leading to breach of sea defences (such as at Dawlish) and trackside fires arising from higher temperatures and reduced rainfall.

4.72 In 2006, research by the University of Birmingham, in a project commissioned by Network Rail, provided a preliminary exploration of the issues and reviewed what had already been published. It concluded that existing studies were highly subjective and rail-specific studies rare. Research can provide evidence about the risks for the railway of changing climate and has the potential to evaluate options for mitigating these risks where they are shown to be significant. However, the impacts are not yet sufficiently well quantified to be able to define specific actions at specific locations, except in the most obvious cases such as Dawlish, where a fully-quantified study has been carried out by RSSB. The uncertainty of climate change prediction is currently large, but better predictions with lower uncertainties should become available in 2008.

4.73 Rail research should increasingly include specific projects to provide quantitative evidence of the effect of climate change on the railways and options for adaptation to these changes. Design standards can then be updated where needed and opportunities for upgrading to meet changes in weather patterns and temperatures exploited.

Optimisation of the network

Network usage

4.74 Mapping of usage and the appropriate application of standards onto the network shows a number of different requirements. Table 4.1 indicates the extent to which the current GB network experiences different types of usage. Where mixed services operate, the route is classified on the basis of the ‘higher’ standards.

Table 4.1: **Differentiation of today's network**

Usage	Track km	%	Route km	%
Fully multi-functional	11,913	41	5,269	35
Suburban only	2,524	9	1,302	9
Suburban and freight	4,967	17	2,488	16
Regional only	1,224	4	764	5
Regional and freight	6,507	22	4,241	28
Regional and community	524	2	395	3
Freight only	1,372	5	756	5
Total freight	**24,759**	**85**	**12,754**	**84**
Total network	**29,041**		**15,203**	

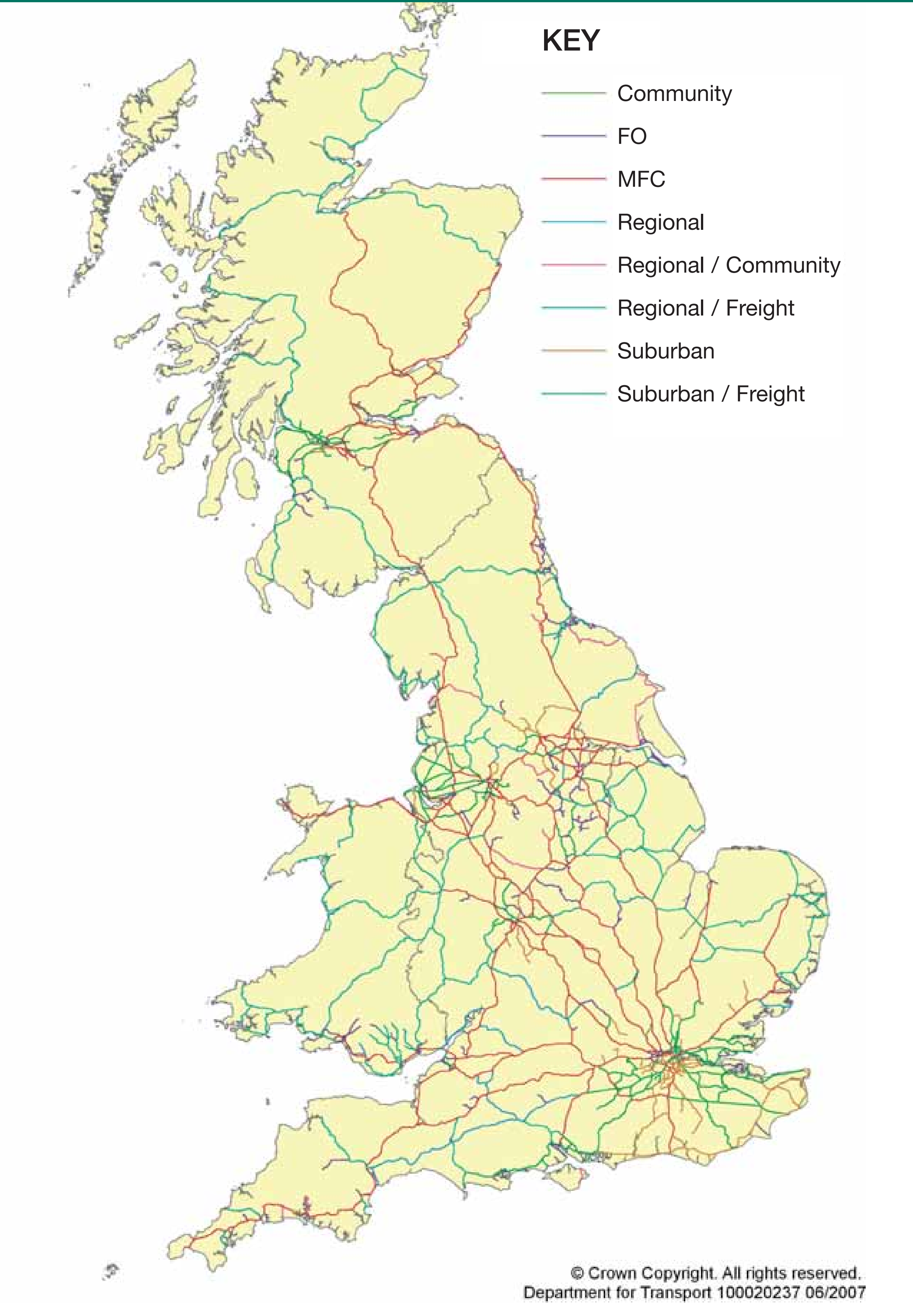
4.75 The fully multi-functional capability currently covers around 35% of the network by route-kilometre, with use by suburban at 25%, regional/community at 36% and freight-only at 5%. At first sight this appears to be a quite even division and suggests that optimisation through differentiation should be simple. However, freight makes some use of 85% of the network, and the differentiation scheme must take account of the need to maintain open access to all routes where there is a reasonable expectation of future commercial need Figure 4.3 indicates the current extent of the identified usages from a differentiated standards perspective.[1]

4.76 Considering the existing and future business requirements of the railway, the RTS envisages the following network segments:

- A 'multi-functional core' of the network, capable of carrying any kind of traffic operating on the network (with the exception of enhanced heavy freight with axle loads exceeding 25.5 tonnes. The multi-functional core will operate in conjunction with network segments subject only to a single type of traffic (or a limited mix) and optimised for the requirements of the traffic types in question;
- A 'suburban metro' railway, optimised to provide high capacity, using simpler, lighter trains with fewer seats operating at relatively low speeds, and high-capacity control systems. The suburban metro segment is characterised by an intensive service with high-capacity trains, short intervals between stops (1 to 5 kilometres), short journey times (20 to 30 minutes), and relatively low speeds (110 km/h or less);
- A 'regional' railway where traffic is lighter and the network needs to be optimised for lower cost, with light trains, light track and simplified signalling systems. A further distinction is made between:
  - 'regional mixed', which allows for use by freight as well as passenger operations; and

1 Scottish Ministers have responsibility for the majority of rail powers in Scotland, enabling Transport Scotland to plan future services and target investment. The Welsh Assembly Government is responsible for the Wales and Borders franchise.

Figure 4.3: **Differentation of today's railway**

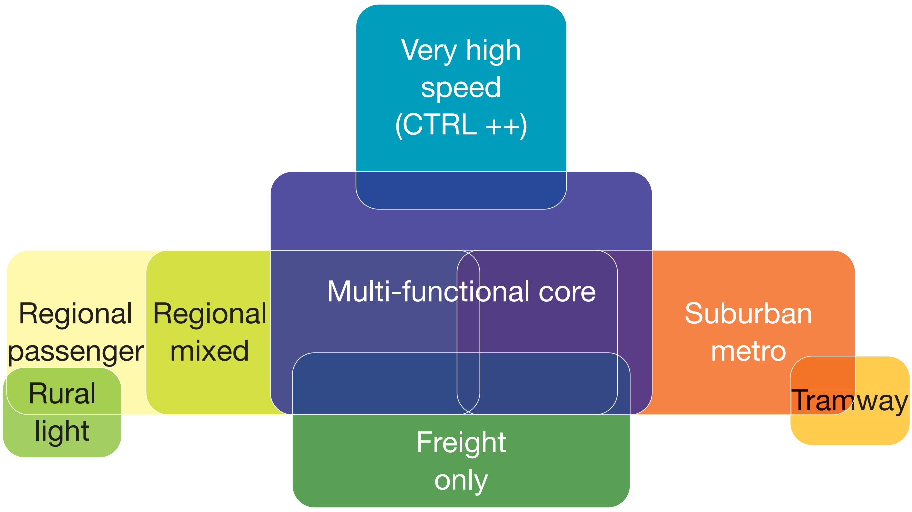


– 'regional passenger', which can be further simplified for the single function, largely in its control and signalling technology.

- Community railways, presenting opportunities for radical technical solutions and further simplification compared with the regional segment;
- Freight-only, not built or maintained to passenger standards, but reflecting the demands of the traffic using each line in question.

4.77 Very high speed lines will fall outside the core. This type of railway already has a specific set of standards intended to optimise the train to the infrastructure, although migration to ERTMS will be expected, leading to greater harmonisation with the national network. No other major change is likely during this period, so this Rail Technical Strategy does not develop this point further. The network segments are shown in Figure 4.4.

Figure 4.4: **Network differentiation**



4.78 The benefits of differentiation will largely derive from specification of infrastructure and signalling. In limited cases, rolling stock may be specified in a way that limits its usage to specific segments without special arrangements (for instance, tram–train solutions for Community Rail, or some locomotives operating only on freight lines that may not be equipped with cab signalling). However, the general expectation is that rolling stock will be suitable for operation across the segments, as most requirements will use the multi-functional core at some point in a trip, daily diagram or cycle of diagrams.

Differentiation and freight

4.79 Freight currently makes at least some use of 85% of the total network, and the impact of differentiation on freight needs to be carefully considered to avoid erecting barriers to open access. The Strategic Freight Network (SFN) described in the 2007 Rail White Paper sets out to address expected increases in coal, aggregate and container traffic.

The SFN generally encompasses the trunk routes between ports and the concentrations of power stations and urban centres, accommodating 775-metre long freight trains with axle loads up to 25.5 tonnes and generally W10 gauge clearance. The majority of the SFN is encompassed within the multi-functional core and regional-mixed segments, but also includes some dedicated freight lines that act as chords or station bypasses. The designation of the SFN should at least be seen as optimising key parts of the trunk network for existing and future freight markets. However, the Freight Route Utilisation Strategy (Network Rail, March 2007) makes it clear that a large part of the network corresponding fairly accurately with the regional passenger and community segments has comparatively low freight usage (between 0 and 1.9 million tonnes a year) but other parts – some of which would also fall into the regional segment – have over 8 million tonnes a year.

4.80 It should therefore be possible to arrange a differentiation scheme which builds on the SFN concept to deliver capacity for freight where it is most required, maintains access for commercial freight on the current basis where there is a reasonably foreseeable commercial need and for the residual part of the network which has no such foreseeable need. The scheme should also maintain means of access for railway maintenance under the control of Network Rail using whatever rolling stock types and conditions give the most cost-effective combination for maintenance of the route in question. The creation of such a scheme will need the agreement of the freight operators and Network Rail, facilitated by the ORR. In support, initial funding of £200m is being made in the first HLOS.

Multi-functional core

Definition

4.81 Whilst some parts of the railway will operate with a narrow set of services, there will always be a large core of the railway network that will need to cater for a wide variety of passenger and freight services.

4.82 This ‘multi-functional core’ broadly equates to the national main lines radiating from London, plus major cross-country routes and much of the suburban area surrounding London and other major conurbations. In the longer term, the scope of the trans-European network should be made consistent with the multi-functional core.

4.83 Some of the identified traffic types would operate almost entirely within the multi-functional core:

- High-speed;
- Interurban;
- Intermodal freight.

4.84 Most other traffic types will use the core for at least part of their activity. Some suburban routes might be isolated operationally, but most will form part of the core or overlap with it.

Technical standards

4.85 The multi-functional core should be designed for RU (Rail Universal) loading as a minimum, to allow for normal locomotive-hauled freight trains with axle loads of 25.5 tonnes.

4.86 Where bulk freight traffic shares the track with high-speed traffic, the track formation must be able to resist higher vertical and shock loadings from the suspensions of freight vehicles whilst maintaining precise alignment for light high-speed trains. Small misalignments will lead to higher forces with heavy freight trains and thus to accelerated rates of degradation. This problem can be reduced by maximising the separation of heavy freight from high-speed passenger routes, which is implicit in the Strategic Freight Network (SFN) concept, by the wider use of track-friendly bogies on freight trains and possibly in the long term through the increased use of slab track.

4.87 Where freight, particularly non-bulk freight, uses routes in the core, increased permitted speeds for freight should be pursued to minimise loss of network capacity and reduce the risk of extension of freight journey times through 'looping'. The deployment of ERTMS will support this by eliminating maximum speeds for freight imposed because of braking performance.

4.88 Equally where there is a requirement for gauge-sensitive trains to use routes in this category, these routes should be cleared to the appropriate gauge – route and gauge to be defined as part of the SFN.

4.89 Where suburban services use the multi-functional core, high stress will be placed on the reliability of switches and crossings. The high densities of suburban traffic will require a move away from the traditional main-line approach of complex layouts with low-reliability components and high theoretical flexibility of operation towards stringent application of 'lean infrastructure' principles, where the service depends critically on a few highly-reliable components.

4.90 Regional traffic will be relatively undemanding; its requirements will be accommodated within those of the other traffic types.

4.91 This core needs to deliver a balance of high-speed and medium-to-high capacity for almost the whole mix of services. It is thus in the multi-functional core that the widest range of capabilities will be required of the network. This presents the most demanding set of tasks, particularly for:

- Control, command and signalling;
- Infrastructure;
- Rolling stock.

4.92 It is these components, therefore, that present most opportunities arising from differentiation of the network segments outside the core.

Suburban metro

4.93 Although the RTS has identified some 1300 miles of route with no traffic other than suburban, this does not necessarily mean that any suburban service-groups can immediately be operated in isolation from the rest of the network, as critical sections such as terminals and their approaches will be multi-user. However, in the long term, physical isolation of suburban service groups should be considered as a basis for more extensive metro-type operations, both in the London area and in provincial cities. The elimination of terminal stations by creating new through routes either underground or through street running is a particularly powerful aid to increased capacity, releasing inner-area terminal and junction capability for other uses.

Control, command and signalling

4.94 Line-capacity enhancement will be achieved through communication-based cab signalling combined with high-reliability trains and infrastructure. This may expose other constraints on network capacity, such as capabilities of junctions and terminals, requiring further work to enable the full benefits to be reaped.

4.95 Dwell times at stations make up a major part of the overall headway, and so it is important that they are both minimised to promote capacity and managed to promote performance. Automatic Train Operation (ATO), one way of eliminating human variation in train handling, is likely to be employed. Control systems, combined with more comprehensive and better-located passenger information displays, can also help to enhance capacity, particularly by indicating in advance where there is space on an approaching train, thus reducing dwell time and enhancing utilisation.

Infrastructure

4.96 Suburban lines carry trains that have high rates of acceleration and braking, and the alignment may be sharply curved. The workload of switches is likely to be considerably greater than on normal inter-urban routes, and particular attention may need to be paid to wear on the rails. Ride quality is also important, since suburban services tend to have a high proportion of standing passengers.

4.97 The challenge is to keep costs down while maintaining reliability. Self-monitoring infrastructure, which can report performance and predict when components need attention to prevent failure in service, will be used increasingly.

4.98 The gauge for new and reconstructed over-line structures should take into account likely future traffic and consider the potential for accommodating double-deck trains.

Rolling stock

4.99 Suburban trains will predominantly be electric. Train lengths are already increasing. Very long or double-deck trains remain options for the long term, but both have high associated infrastructure costs. Communication-based cab signalling and Automatic Train Protection (ATP) will be provided for. Trains will be designed for low tare weight, high passenger capacity (with a higher proportion of standing passengers) short dwell times (achieved by having wide doors and large vestibules) and high acceleration. A consistent approach to toilet provision needs to be adopted across both rolling stock and stations.

Regional (passenger and mixed)

4.100 Regional railways will in general not produce a rate of return that can meet the costs of infrastructure at 'multi-functional core' standards. It is in these segments that costs must reduce, and indeed where differentiation offers the most scope.

Control, command and signalling

4.101 In practice most trains on the regional network will also operate at some time on core routes and so will have to be equipped with compatible cab signalling facilities, which can then be employed on the regional network to the extent that the fixed equipment is justified.

4.102 The cost of train control should fall rapidly once real-time train location becomes universal. It is likely that operations on most regional lines will be controlled from an operations centre, probably through low-cost data radio such as GSM-R (GPRS), the future development of which will allow increased capacity for train control systems, regulation, improved passenger facilities and operational support services.

4.103 In areas used only for passenger services and where speeds are relatively low, signalling can be minimised, using 'Regional ERTMS' principles. If trains are fitted with track brakes, trains may be allowed to operate with no signalling at all, running instead under 'line of sight' rules, although track brakes also increase train mass and complexity.

4.104 Regional trains that run for part of their journey on the multi-functional core will need to be fitted with communication-based cab signalling. This can be used to support low-cost, minimal-infrastructure ATP where service levels justify it and in 'regional mixed' areas be used by both passenger trains and freight services.

Infrastructure

4.105 Maintenance of regional routes has generally been restricted to that required for safety, rather than driven by efficient life-cycle criteria based on sustainable operational limits. It is unlikely that these routes will in future command the resources necessary to support a major increase in track quality. The major change for the future will be in rationalising the standards of infrastructure to serve different types and levels of usage, because the regional category in itself covers a wide variety.

4.106 At the lightest level will be the lines carrying lightweight multiple-unit passenger stock only. The track for these lines will be maintained at the appropriate standard of alignment to provide adequate ride quality for passenger services at the speed for the line and at a design loading down to as little as 10 tonnes per axle. The methods by which occasional freight and railway maintenance users can comply with such a limit on infrastructure will need to be determined, but a number of options including lightweight locomotives and freight multiple units are available.

4.107 Access opportunities for maintenance will be more restricted, and the use of mechanised maintenance will be required, although the track alignment standards and thus intervention intervals will be less than for the multi-functional core. The maintenance regime will be component replacement rather than wholesale renewal, as the rate of deterioration will be very slow with the light loads. The service levels will be such that low-tech, manually-intensive maintenance will generally be possible without disruption to traffic. When renewal is required, the options of lightweight track or cascaded used track will be used, depending on life-cycle cost and availability. Further research needs to be done by Network Rail to demonstrate the relationship between occasional use by heavier trains and infrastructure cost, where lines are normally used by lightweight passenger trains.

4.108 Some regional lines will carry occasional heavy freight in addition to light passenger services. These freight trains may apply heavy axle loads of up to 25 tonnes, but speed can be restricted over sensitive structures. The high axle loads will raise the level at which component replacement is required, but this level of maintenance would still be appropriate in general. The service levels will still be such that low-tech maintenance will be possible without disruption to traffic. Renewal is likely to be with cascaded used track.

4.109 Some regional lines will be required to handle regular freight traffic and may form part of the strategic freight network, or a freight diversionary route, or a strategic access route to a commercial freight terminal. The track construction standard for these lines would be similar to the heavy-freight lines, with track alignments suitable for passenger services.

Rolling stock

4.110 It is unlikely that the level of service on much of the regional network could justify the cost of electrification, unless this becomes very much cheaper. Rolling stock will therefore be lightweight and based on portable energy, but will incorporate regenerative braking and energy storage where economically justifiable. Where a large part of a route is dedicated to regional passenger services, tram–train type lightweight vehicles with track brakes may be an appropriate solution.

Community railways

4.111 Community Rail Development Strategy covers the relationship between the railway and the community it serves, as well as technical issues, and as a result designations already made overlap considerably with the regional passenger viewpoint provided above. Community rail services will run on dedicated lines and on passenger-only regional railways. They are not expected to run on freight-only or high-speed lines, but may need to run onto inter-urban, regional or suburban routes to complete their journeys.

Control, command and signalling

4.112 Solutions are likely to be bespoke for each set of circumstances, especially where operations can be isolated from the rest of the network. High-performance track brakes could make signalling redundant in many areas and, where it is necessary to inter-run, special train protection can be provided on the main line part of the route.

Infrastructure

4.113 Infrastructure will be similar to regional passenger routes. Minimising the maintenance and renewal cost is the challenge. These lines can generally be maintained by small teams with good local knowledge using low-technology methods.

4.114 Community rail lines should be able to be designed to RL loading. The needs of the particular line and traffic should dictate the minimum structure gauge; however, where the cost of providing standard gauge structure is not unreasonably greater than the minimum, the standard gauge should be used.

4.115 Community rail lines are unlikely to be electrified (although some such lines currently are).

Rolling stock

4.116 Rolling-stock solutions for community routes will be procured on a case-by-case basis, reflecting the circumstances of each line, and probably driven by an overriding requirement for affordability. Innovative solutions will be sought, but heritage rolling stock may well continue to be used on some lines, especially for tourist traffic.

Freight-only

Control, command and signalling

4.117 Freight locomotives will be fitted with standard cab signalling system unless captive to freight-only lines and yards. It is therefore likely that the most economic solution for freight-only lines supporting multiple train operations will be to fit the low-cost infrastructure element of the system. Operation by voice radio and train order, although currently a widely-used mode in North America and elsewhere, appears likely to have been superseded in the USA by Positive Train Control (a simplified ERTMS equivalent). 'One-train working' lines will still not need signalling.

Infrastructure

4.118 Routes within the freight-only segment will be maintained to cater for the intended usage; they will normally be designed for Rail Universal (RU) loadings and could be enhanced on specific routes, where the additional costs are justified by the market, for axle loads of up to 35 tonnes.

4.119 Track standards on lines that carry bulk freight will focus on the need to support heavy vertical loads on plain track combined with heavy side loads on curves and points. Planned maintenance interventions will be based around impacts on safety and degradation rates. The case for the use of slab track on heavily used sections has yet to be made.

4.120 The gauge for freight-only lines should match the business need, both immediate and potential, and align with the standards adopted for other types of network with which they are connected. New or reconstructed structures on existing route should pass UIC gauge GC as a rule, with W12 capability as a minimum.

4.121 It is unlikely that freight-only lines will be electrified, as the power supply arrangements may conflict with high-capacity automated loading and unloading facilities, and it is unlikely that frequencies would make up for the diseconomies of a traction change. However, electrification could be advantageous in specific cases to complement the multi-functional core and allow for through-haulage by electric traction.

Rolling stock

4.122 Where freight locomotives run on the multi-functional core, they will need to be fitted with communication-based cab signalling. Where they operate only on dedicated freight-only routes at low density, fitting will follow the risk-assessed decision as to whether the route is equipped for low-cost cab signalling or line-of-sight operation.

4.123 Main-line freight locomotives are traditionally designed for 'go-anywhere' operation using diesel traction, and the existing fleet is made up of modern and increasingly ubiquitous Class 66 diesel locomotives. Because these are not restricted to particular routes, freight operators are unlikely to adopt electric traction widely until electrification covers 70% or more of the network, or unless the economics of carbon make changing locomotives en route cost-effective. Regenerative braking will be in use for electric freight trains, with speed curves matched where practicable to locomotive braking ability. Shunting, short-trip and engineering-maintenance locomotives, however, are a particularly attractive target for hybrid traction because of the need for low emissions and low noise, and units such as the Canadian/Swedish 'Green Goat' are likely to be universal in this niche. Hydrogen fuel-cell traction is a possibility for freight, and a 1 MW locomotive is already under development in the USA, but a renewable supply of hydrogen remains the key issue for this technology.

4.124 Where required, some freight vehicles may exploit a capability for axle-loads up to 35 tonnes, improving the ratio of payload to tare weight. At the other end of the scale, freight multiple units are likely to remain in widespread use for infrastructure maintenance and may extend into the commercial freight area, particularly where high performance and low track impact are needed to match available slots on single-track regional lines.

4.125 A key technological issue for freight, which will allow maximum advantage to be taken of ERTMS, is the development of a dependable train integrity system, providing continuous confirmation that a freight train remains in one piece.

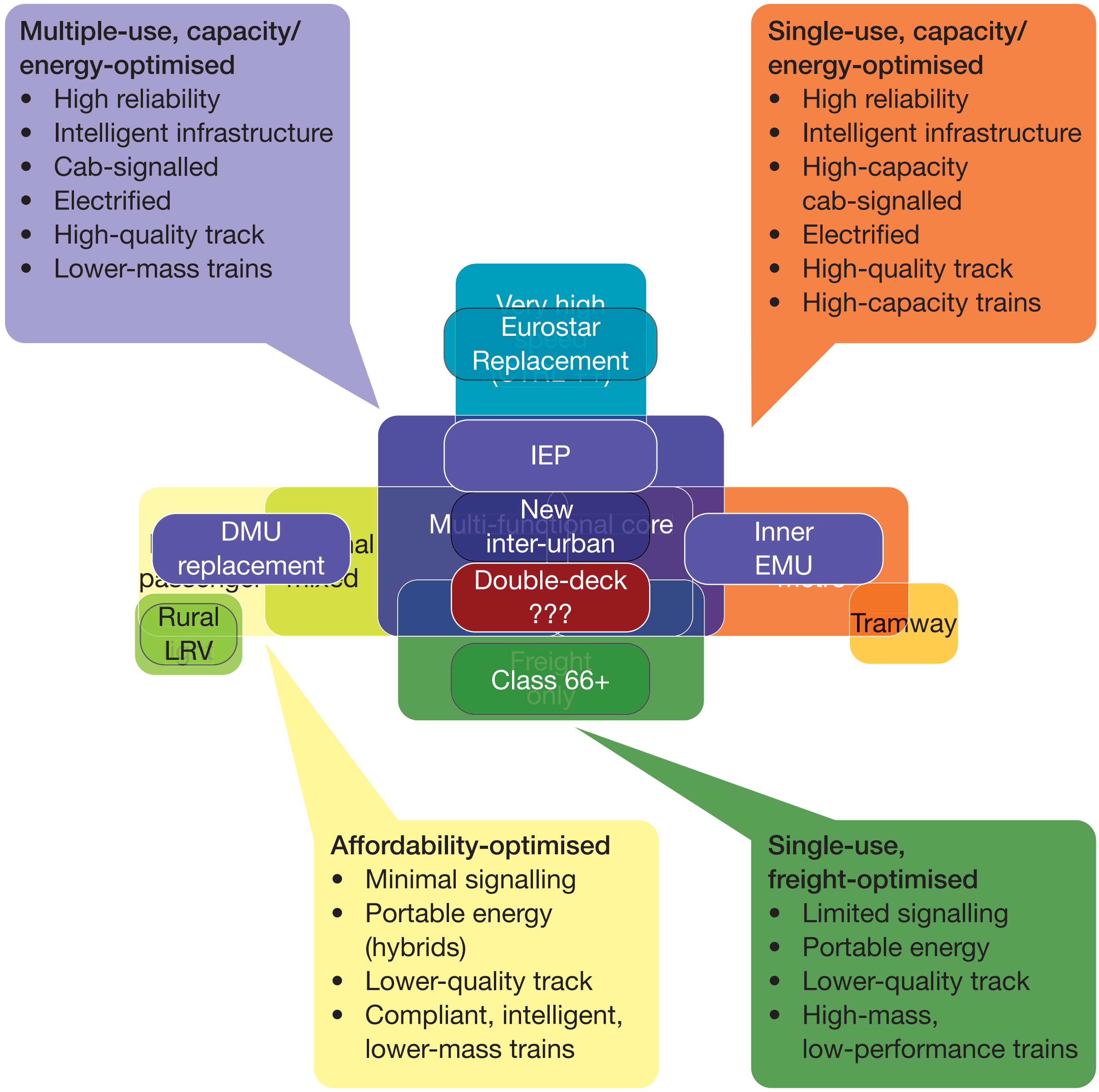
Summary

4.126 Key impacts of the differentiation embodied in the engineering vision are summarised in Table 4.2 and Figure 4.5.

Table 4.2: **Summary of segments and sub-systems**

Segment	Optimised for:	Infrastructure	Energy	CoCoSig	Rolling stock
Suburban metro	High passenger capacity	Highly reliable Maximum availability Track layouts for maximum capacity Station layouts for high throughput and minimum dwell time No gauge enhancement	Electrified	ERTMS Level 3 Satellite-based positioning with high-precision support Full system management and driver advisory speeds or ATO Track-based detection and fallback signalling at key junctions	Light High acceleration – powerful but low top speed High capacity with ease of access/ egress to give low dwell times Compromise on comfort and facilities
Regional mixed	Affordability	'Go-anywhere' light axle load for passenger trains As multi-functional core for freight trains Minimum intervention Gauge enhancement as required to reflect routing of gauge-sensitive trains	Non-electrified	Regional ERTMS providing full protection but with minimal infrastructure Limited system management facility Driver advisory speeds only at critical locations	Low axle load for passenger services. As multi-functional core for freight Capable of operation into the multi-functional core
Regional Passenger	Affordability	Low axle loads Minimum intervention No gauge enhancement	Non-electrified	Simplified – regional ERTMS with zero infrastructure Possibly line of sight	Energy efficiency and good accessibility Potential to run through to street-running at urban stations
Freight only	Minimum whole-life cost	For very high axle loads – up to 35 tonnes Designed for minimum intervention Gauge enhancement Gauge enhancement as required to reflect routing of gauge-sensitive trains	Electrification possible depending on economics of fuels and energy	Simplified – ERTMS regional or conventional	
Community	Affordability	Low axle loads Minimum intervention No gauge enhancement	Non-electrified	Minimal – line of sight where practicable	Bespoke and innovative solutions Interoperation compromised, special arrangements if required

Figure 4.5: **Differentiation summary**



Traffic operations and management

The end-to-end journey experience

Passenger information and management

4.127 The station is the link between the train and the rest of the overall journey; it will face increasing challenges as demand increases and passenger flows intensify.

4.128 Greater emphasis will be put on services being planned to take into account other modes of transport, including corresponding services with bus, metro and light-rail lines. Services will also operate to and from established and new railheads, such as park-and-ride schemes.

4.129 The integration of services will encourage a modal shift from private to public transport systems. Easy access and clear interchange between transport modes, along with adequate car parking provision, will be important. Availability of car parking currently presents a barrier to rail use at many locations that have experienced significant growth, and the cost of parking can be a significant part of the overall cost of a journey. Easy and safe access to stations from walking and cycling routes will be equally important, and positive segregation from motorised road traffic will be looked for in highway plans. Innovative schemes such as cheap local cycle hire to encourage cycling as the final transport link to destination are already in use in Scandinavia and Holland; such schemes reduce the demand for space on trains.

4.130 In the urban area of the network, compromise on comfort and on-board passenger facilities will continue to be accepted in order to provide the capacity needed. In the peripheral areas of the network (rural and secondary lines), compromise on station facilities and accessibility may have to be accepted in order to meet needs at an acceptable cost. Key features will be:

- Effective use of ticketing, passenger flow, train movement and train load data will give high-quality information to passengers prior to and throughout their whole journey, highlighting lowest-cost options, available capacity, alternative services, routes and modes and options for journey completion including bus, taxi and bicycle;
- Active management of intended journeys to exploit available capacity and support the end-to-end experience;
- Continuing emphasis on creating a safe, secure and attractive environment on and around stations and on trains.

4.131 Many aspects of the journey experience will derive from fast-moving developments in communications, and the future in this area is difficult to predict because the technology is changing very fast. Train operators will continue to lead passenger-facing developments, but the common need for comprehensive and accurate real-time information will encourage co-operative action: operators working together and with Network Rail to develop systems to supply it.

4.132 Recent massive changes in consumer communications have brought expectations that what are now everyday facilities (such as mobile telephones and internet access) will be available on trains, and these are being delivered now. It is expected that the consumer markets will continue to develop, and the railways will need to exploit these developments by:

- Providing passenger facilities and information which allow the railway to provide the key link in a competitive end-to-end transport service;
- Utilising technology development for its own information, control and management systems;

- Adopting integrated standardised cashless ticket facilities such as smartcard, mobile phone and Radio Frequency Identification (RFID).

Station design and operations

4.133 Network capacity can be significantly affected by design and use of stations, and this will become more critical as usage intensifies. At through stations, particularly in suburban areas, dwell times are a significant component of the headway and are thus likely to be a critical factor in line capacity. To some extent improvements can be made by passenger-management measures. In the longer term, the number of access points and their relationship with trains will be a significant factor in reducing dwell time, by distributing passengers along the train rather than concentrating them into a few coaches. Platform stepping distance (often exacerbated by platform curvature) may also affect dwell times.

4.134 The capability of a terminal station to turn round and despatch arriving trains is also a key determinant of network capacity, and even where not binding now may well become so as capacity constraints elsewhere are eased. As infrastructure and equipment reliability improves, the contingency element in the minimum 'Rules of the Plan' turn-around times might be reduced, particularly for long-distance services. However, as passenger capacity per train increases, the element of the turn-around time required purely for passenger purposes may increase, especially as for long-distance and irregular customers the ability to board a train and settle in well before departure is an advantage.

4.135 Increases in turn-around time purely for passenger purposes may be mitigated by station facilities, in that passengers may be willing to tolerate last-minute boarding if station waiting areas are comfortable, well provided and close to not just the intended train but the intended vehicle (in contrast with just a place in a queue or mass near the departure boards, followed by a rush for seats the length of the train as the platform for a departure is announced). As an alternative to the traditional concourse behind the buffer-stops at terminal stations, a circulating area on a separate level with distributed accesses to each platform would be an improvement. This would also facilitate separation between passengers and service vehicles such as bowsers, buggies and catering-supply vehicles, and even between alighting and boarding passengers.

4.136 Luggage handling is a neglected area in railways when compared with air travel, and this may put people off travelling by train. Luggage trolleys are used in a few main stations, but thinking needs to go beyond this and consider innovative ways of handling heavy personal baggage.

4.137 An element of turn-round time will continue to be needed for cleaning, servicing and catering re-stocking between trips, but may be reduced by technological developments such as reliance on electronic displays for reservations in place of individual seat labels. Some allocation of time at termini for security purposes, as for international services, may become necessary on domestic services.

Train operations

Movement control

4.138 The pressure to maximise service reliability and availability will reinforce the move towards integrated control, with the extensive use of technology for automatic system regulation in normal conditions and decision support in abnormal conditions. Passenger information will be well integrated into the system, with open access to train-running information and a high priority given to response to service recovery.

4.139 New system-management technology combined with accurate knowledge of train position will give the opportunity to present drivers with advisory speeds as well as safety-critical speeds, aimed at maintaining the flow of traffic by regulating trains in advance of points of conflict so as to avoid or minimise the need to stop trains to await paths. This will be particularly important where routes are shared with freight services, enhancing the ability of the control system to keep freight moving and avoid time-consuming stop/start cycles. Additional benefits will be gained through reducing the amount of energy used by allowing drivers to coast when ahead of schedule.

4.140 The capability for bi-directional operation offered by ERTMS will promote working round line blockages.

Capacity and planning

4.141 Communication-based cab signalling combined with high reliability trains and infrastructure will allow the 'Rules of the Plan', which govern the allowances built into timetables, to be rewritten in favour of a substantial increase in network capacity, first by reductions in the minimum headway as block lengths are reduced and movement authorities are tailored to each train's speed and braking characteristics, then by mitigating extremes of headways where fixed signals are currently not optimally located, for instance because of sighting problems, relationship with stations or junctions, or parallel location on multiple track routes. Benefits can also be taken in the form of:

- Service performance, if not all of the additional network capacity is used, in effect adding to the contingency element ('white space') in the timetable;
- Service frequency, if additional network capacity is both created and used, and by the intelligent management of train movements, allowing a reduction in the contingency element in timetables (performance time and 'white space'), without detriment to overall service performance.

4.142 Factors that constrain the network capacity, such as terminal capabilities and the mix of fast and slow trains, will be addressed first by the reduction in turn-round times and operating margins that will be possible in a high reliability system, and only then by increasing the number of platforms, by the addition of passing loops and grade-separated junctions.

4.143 The creation by Network Rail (for maintenance and operational reasons) of a linked asset database covering trains and infrastructure, together with improvements in modelling and computing power, will make it possible to adapt and change timetables much more responsively and predict the effects of short- and long-term change more accurately.

4.144 Although the broad pattern of freight movements is relatively stable geographically, the trains actually to be run day by day may vary significantly. Considerable emphasis will therefore still need to be placed on smart and fast scheduling, as well as on prompt recovery from perturbations.

Train operations

4.145 Train control centres will need to be able to respond rapidly to incidents as the network reaches full capacity at its pinch points and occupancy times at key junctions and stations become critical to maintaining the service. Continual contingency planning using credible scenarios and based on real-time data will ensure that, once an incident occurs, then the service recovery plans and plans for degraded-mode operation can be brought into effect immediately.

4.146 Movement towards integration of control centres to encompass both network management and train operations functions can be expected to continue, but may not become complete, as specialist operators may find that effective internal organisation outweighs the benefits of integration, and in these cases effective communications will be the key.

4.147 Stabling and train preparation procedures will reflect the need to reduce the amount of energy used, with automatic systems such as lighting, heating and air-conditioning control able to cut out equipment when it is not required.

4.148 Enhanced support to drivers from advanced signalling systems will allow an easing of the constraints imposed by route knowledge. This will have the effect of reducing training time, thus reducing costs, and providing increased flexibility in the event of disruption requiring diversionary routes to be used. Greater commonality in control and safety systems will also reduce training periods. The aim should be that train drivers require similar levels of technical and operational knowledge to coach and truck drivers.

Staff and skills

4.149 The railway is and always will be dependent on its staff for safe and reliable operation, providing the direct customer interaction and flexibility of response that only human intervention can provide. However, it would be unrealistic to expect that either people or the work they have to perform on the railway will stay the same over 30 years. It may become more difficult to acquire and retain staff to carry out work at unsocial hours – even more so if the work is exposed to weather or staff have to deal with threatening behaviour from customers.

4.150 The expectations of staff for information and support will change, along with those of the general public, and the railway envisaged in the RTS will provide much more automated support to its staff. Drivers will be provided with supporting information in real time that enables them to drive in the most energy-efficient way consistent with the timetable and the state of the network; in some areas they will also be able to switch to automatic train operation. ERTMS will deliver movement authority directly into the cab and will provide continuous supervision of speed compliance. Signallers will be provided with comprehensive automated support consistently across the network. The system will predict and manage normal train movement, leaving staff free to concentrate on passenger-focused tasks and handling abnormal events. Conductors and guards will be provided with information on train running for both their own train and others in the area. Although centralised control works well in normal conditions, both train and station staff will need local autonomy to control displays and announcements from a roving position when disruption occurs.

4.151 Competencies will also change over time in many areas, particularly those related to maintenance and operation. The need for detailed knowledge of railway geography is likely to reduce as automated systems are extended and become more reliable, but the need for understanding of railway systems is likely to increase, especially in relation to response in disrupted and abnormal conditions. As reliability increases, experience of failure reduces, but this can be offset through the increasing availability of cheaper, more realistic and more powerful simulation.

4.152 The recruitment, training and retention of skilled staff will continue to be an area that needs proactive engagement from industry bodies. Staff with the combination of theoretical and practical skills needed for railway operation and maintenance are likely to be in increasingly short supply. Technology will increasingly support training.

4.153 The 2004 White Paper *The Future of Rail* highlighted the need for Government and industry to continue working together to raise the profile and sharpen the focus of the rail skills agenda. One of the key outcomes has been the establishment of the Rail Industry Skills Forum (RISF) to provide strategic advice on future skills requirements for the industry.

4.154 The RISF includes representatives from Network Rail, ATOC, London Underground, the Rail Freight Group, the Railway Industry Association, along with the DfT, Go-Skills, the Science, Engineering and Manufacturing Technologies Alliance and the RSSB.

4.155 RISF has been set up to take an holistic view of the industry's skills framework to help ensure that its many parts attract, develop and retain the necessary skills required to deliver the future railway system. Whilst responsibility for delivering skills training remains firmly with individual organisations, the RISF is to carry out a foresighting study to predict competence and staff needs over the next 4–30 years and will provide a focal point for the industry by:

- Providing a collective rail industry voice on skills development and improvement issues;
- Facilitating strong working relationships between the industry, trade unions, sector skills councils and the wider Skills for Business Network;
- Assisting in the strategic direction for the RSSB Research and Development programme in workforce development and competence, which is funded by the Department for Transport;
- Helping to align the industry with the Government's initiatives in skills development outlined in the Leitch Review of Skills report; and
- Helping to promote the industry to potential entrants.

4.156 The formation of the RISF is an important step forward for the railway network. It has succeeded in bringing together relevant stakeholders with a direct interest in rail industry skills. Importantly, however, it has the capability to make a genuine difference to the way the industry positions itself in facing up to the present and future skills challenges.

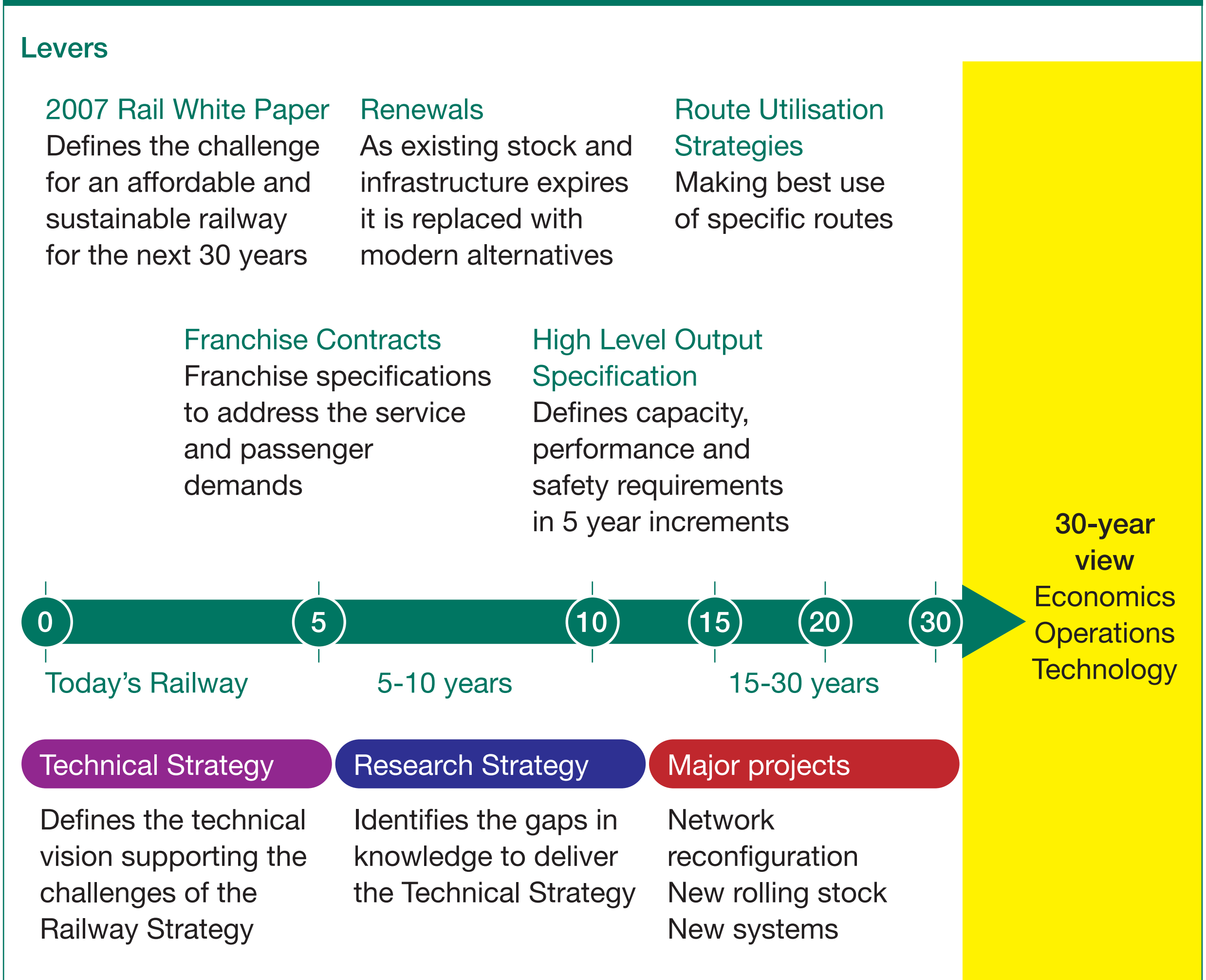
5. Implementation

Road map for change

Levers

5.1 The process of development of the RTS has illustrated a number of lessons. Major change will only be possible if there is clear leadership, close co-operation between Government and the key parties responsible for delivery, and broad support across the industry. Each party must recognise the part it plays in creating and delivering change, and the interdependence with others. Leadership must come from those with the incentive to maximise whole-system benefit and to minimise whole-life, whole-system cost, and it is clear that Government needs to play a full part.

Figure 5.1: **Defining and delivering the future railway**



5.2 The available levers for change (Figure 5.1) are:

- **The 2007 Rail White Paper** containing the overall strategy for the railway. Government has set out in this document the future needs that the railway is expected to have to meet over the next 30 years. The RTS is subordinate to the 2007 Rail White Paper and reflects the major strategic drivers in it;
- **The High Level Output Specification (HLOS)** specifying the desired outputs (in terms of safety, service performance and capacity) over the next control period. Government has delivered the first HLOS covering the period from 2009 to 2014. The DfT would expect the principles set out in the RTS to be considered by Network Rail and ORR in the evaluation process to the extent that they are, or should be, reflected in Network Rail's asset policies for the HLOS period in order to deliver a whole-life, whole-system cost benefit;
- **Route Utilisation Strategies (RUS),** which establish detailed plans for rail services, making best use of current trains and infrastructure at route level. Future work should start to reflect the principles of the RTS once the planning horizon extends sufficiently;
- **Major projects,** which deliver change to the infrastructure or trains, or both. Major projects are delivered over long time-periods and need to be consistent with the RTS in terms of their deliverables over time. In order to achieve this, innovative solutions need to be developed to the point where they represent a reasonably low technical risk before major projects will commit to them;
- **Renewal and refurbishment** of rolling stock and infrastructure. Network Rail has asset policies that provide a framework for renewal and is developing a ‘Future Railway’ programme that is consistent with the RTS. The DfT is developing a rolling-stock renewal strategy influenced by the RTS;
- **Research** can validate and influence the long-term view and help to provide innovative solutions consistent with the principles of the RTS.

Opportunities

5.3 Successful and cost-effective implementation of the RTS will exploit opportunities presented by routine replacement of major assets and major enhancement programmes, and the opportunities presented in the results of further research. This process of exploitation needs to be carefully planned, so that elements of the RTS add value in the short to medium term, meet affordability criteria and do not conflict with day-to-day operational needs, whilst being seen to deliver a key part of the necessary long-term change.

5.4 The major renewal and enhancement programmes that must be linked with the RTS are:

- **Re-signalling:** Given that conventional electronic signalling installations tend to have a life of around 25 years, most installations will fall due for replacement within a 30-year time horizon. ERTMS in the UK is currently at the stage of an operational trial, so conventional re-signalling will continue for the first few years. However, Network Rail has already selected ERTMS as its future asset policy. ERTMS will be applied to major re-signalling schemes from approximately 2014 onwards, starting with East Coast and Great Western Main Lines;

- **Intercity Express:** The Intercity Express Programme (IEP) has already initiated a process that will replace the high-speed diesel and electric trains developed in the 1970s and 1980s. Targets for lower mass, higher capacity and better energy efficiency than recent train designs are being set, and Network Rail has committed in principle to make the supporting changes to the infrastructure;
- **New-generation multiple units:** Beyond IEP, the major opportunities are replacement of the electric and diesel multiple-unit fleets introduced in the 1970s and 1980s. The DfT is initiating a multiple-unit replacement programme with two major targets to be addressed in parallel. The first aims at a high-efficiency, low-mass train capable of replacing diesel multiple units reaching end of life from 2012 onwards. The new trains will incorporate low-emissions technology and will have flexibility to operate on or off electrified infrastructure. The second aims at a simple, high-capacity, high-performance train for inner and outer suburban use on electrified lines, starting with Thameslink stage 2. These projects represent an opportunity to develop the concept of the 'rational family', particularly in terms of a range of standard body-shells in high- and low-density variants. All future electric units will be capable of regeneration, and provision will be made for incorporating hybrid technologies into new diesel traction packages;
- **Smart ticketing (ITSO):** The DfT and ATOC have initiated a smart-ticketing programme, starting with South West train services out of Waterloo and a condition of the recently awarded East and West Midlands franchises and the New Cross-Country franchise. This programme represents a major opportunity to provide improved cross-modal facilities as well as creating the structure within which a much more flexible fares policy can be applied, aiming to optimise utilisation of services. Data from the system will also support real-time passenger counting and improved passenger information;
- **Thameslink:** Planning for the Thameslink Programme is well advanced, and the first stage can be delivered with conventional technology. The second stage should be based around the new train design outlined above and will need to be fitted with ERTMS, which also offers an opportunity to support the capacity needs of the core route in a cost-effective manner, provided the next stage of development can offer an improvement in signalled headway. The control and regulation opportunities presented by communication-based cab signalling and driver advisory speeds will be needed, as will improvements to passenger handling and information systems;

- **Crossrail:** Crossrail is designed to enhance capacity on the main east–west corridor and to ease crowding on services into Paddington and Liverpool Street, as well as providing some crowding relief from south-east London. An enabling Bill for Crossrail is currently before Parliament. The opportunities are very similar to those outlined for Thameslink. A key difference is that a decision has already been taken that ATO is needed for the Crossrail tunnel section. Since the trains will have to be fitted with ERTMS for the outer areas, the most satisfactory solution would be to use ERTMS also for the tunnel, thus avoiding duplication of onboard systems. Although no problems of principle are envisaged in developing an ATO system to operate with ERTMS, this has not yet been achieved anywhere in the world.

5.5 Further opportunities may arise from within existing projects and programmes, from research topics that look to address the knowledge gaps identified by the RTS and from considering technology and operational developments in other industries.

Migration

5.6 The achievement of the changes set out in this document will be complex and involve cultural, human, regulatory and legal as well as technological and operational factors. A key to overcoming barriers is to set out a clear migration path to achievement of the engineering vision, to a point where the basic technical and operational feasibility of making changes of the kind discussed, over the timescale of the RTS, has been demonstrated.

5.7 It is very clear at the start that some of the changes discussed are complex and interactive, whereas others are relatively ‘stand-alone’. The most complex are those that change the various technical and operational interfaces between trains and track, as these need to be sponsored and planned on a whole-system, cross-industry basis.

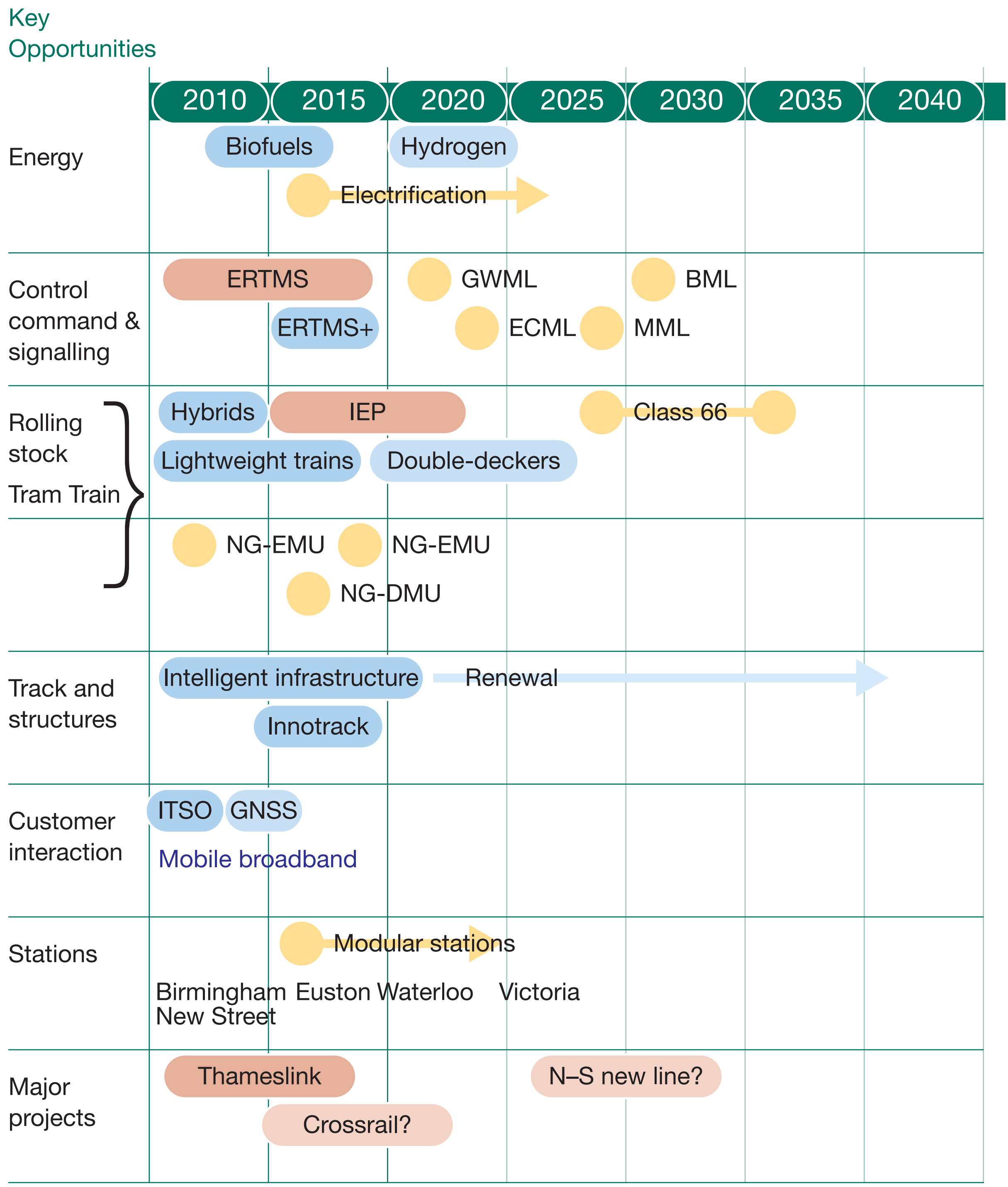
5.8 The interface between track and trains may be considered at two levels (Table 5.1). At primary level, changed trains cannot run unless a compatible change has been made to the track. At secondary level, trains can still run, but with some impact on system performance or passenger expectations.

Table 5.1: Changes to the railway

Change	Interface issue?	Comment
Communication-based cab signalling	Primary	Unfitted trains cannot run in fitted area. Requires rollout coordinated between route geography and rolling stock cascade. Also resolution of funding locomotives whose 'go anywhere' nature will dictate whole fleet fitment at an early stage. Changes to operating rules and signalling principles.
Electrification	Primary	Electric trains cannot run in unfitted area. Requires rollout coordinated between route geography and rolling stock cascade, but bimodal and energy storage trains will provide a more progressive transition.
High-reliability trains and infrastructure	Secondary	Full benefit cannot be realised until all trains on a route are high-reliability. Older train failure may impact performance on an upgraded route being crossed.
Light passenger trains, precision track	Secondary	Trains might have to run at reduced speed or accept shorter train life and less comfortable ride on unmodified track. Where route also has to handle freight, the technical specification must reflect this.
High-accuracy positioning combined with advisory speeds and better system management	Secondary	Energy benefit partially realised on a per-train basis. Full benefit, including capacity, only when all trains fitted.
Hybrid and other advanced propulsion	None	Changes in fuel will have to be coordinated on a cross-industry basis.
Customer information	Secondary	Train-borne systems will need to be fitted to all trains in an area to get full benefit.

5.9 It is clear from the table above that the major issues from a migration point of view are communication-based cab signalling and electrification. In economic, although not in strictly technological terms, these two are also linked to each other, because electrification is made significantly cheaper and easier to implement if applied over cab signalling. Both are also linked to rolling-stock strategy. New, lighter trains such as IEP that depend on improved track quality to deliver their full benefits have an obvious linkage to track renewal. It is therefore clear that, as well as the technical migration issues associated primarily with cab signalling, a strong element of strategic planning is needed to control the migration of the network through the changes envisaged for the next 30 years. Figure 5.2 illustrates this process.

Figure 5.2: **Timeline of major projects, renewals and areas of research**



Incentives and benefits

5.10 It is unlikely that legislation will play a significant part in delivery of the RTS, other than through European directives. If the Strategy is to be delivered, therefore, it requires either that benefits are aligned for the various partners involved, or, where they are not, that incentives are created through the ORR or Franchise Specifications.

5.11 For the industry overall, the principal benefits of the RTS are clear:

- Higher revenue through higher capacity;
- Lower energy and carbon costs;
- Lower maintenance costs;
- Improved competitiveness with other modes;
- More adaptability to run varying services.

5.12 For the customer, the principal benefits are:

- More reliable, more adaptable service;
- More trains, so less crowding;
- Better information on services, space availability and connections;
- Better station facilities;
- Improved connectivity with other modes;
- Better accessibility.

5.13 The RTS needs to look into the future, considering how the current initiatives will work and whether they are likely to prove fit for purpose in encouraging delivery of the kind of railway that is needed for the future. Table 5.2 summarises the current incentive set against the themes for change adopted in this Strategy.

5.14 Table 5.2 shows not only considerable common interest but also the possibility of divergence, particularly in the areas of cost, carbon and capacity. It reinforces the view that, within the current structure, a proactive approach to create partnership between the industry parties based on up-front clarity on the balance of costs and benefits is essential to deliver change. Better alignment of incentive structures should be given priority.

Table 5.2: Incentives and themes for change

Area	TOCs	FOCs and Open Access Pass	RoSCos	Network Rail	DfT
Whole-life, whole-system cost	Operational cost over period of franchise	Whole-life cost of assets	Lease income versus whole-life cost accruing to RoSCo	Whole-life cost for infrastructure assets	Whole-life, whole-system cost and affordability moderated through RAB
Carbon emissions	Energy cost	Energy cost	Residual value of trains	Energy cost of own operations	Total energy cost of network moderated through franchise agreements and RAB
Capacity	Increased revenue from franchised services	Increased total usage of network if additional capacity becomes available	Increased number of trains	HLOS requirements	Minimised crowding; efficient use of assets. Delivery of Eddington/Stern objectives
Customer	Increased passenger usage of franchised services	Increased total usage of network if additional capacity becomes available	Response to passenger needs reflected through TOCs. Residual value of trains	Station usage and income. Safe and efficient movement through system	Efficient use of assets
Safety and security	Legal obligations to customers and employees. Customer retention. Reputation. Avoidance of disruption	Legal obligations to customers and employees. Customer retention. Reputation. Avoidance of disruption	Legal obligations to employees. Residual value of trains. Reputation	Legal obligations to train operators and employees. Reputation Avoidance of disruption	Political and departmental reputation. Effective use of assets. Avoidance of disruption

Road map for change

5.15 In taking forward any complex change in any reasonably complex organisation, the barriers that exist (or are perceived to exist) must be recognised and addressed.

Standards and rules

5.16 Standards are perceived by the industry as a major barrier to change. The development of Railway Group Standards (RGSs) is the responsibility of RSSB. The management and development of Technical Specifications for Interoperability (TSIs) is the domain of the European Railway Agency. The intention of both TSIs and RGSs is to provide a framework for system safety by setting out clear, concise and cost-effective standards that encourage compliance. TSIs go further, as they are intended to promote interoperability and improved economic performance. RSSB has integrated the management of RGSs with its work to support the industry on the development of TSIs. RSSB has a comprehensive programme for standards update explained in the Strategy for Standards Management, which is driven by the two principles:

- That Group Standards cover only those areas where there is an interface between infrastructure managers (Network Rail) and railway undertakings (TOCs), leaving other areas for duty-holders to define their own solutions/standards; and

- That over time RGSs should migrate to be the same as the relevant TSI (i.e. the domestic and the European standards should be the same – with the best solution being promoted for inclusion in both).

5.17 When considering the need for long-term change of the railway system, it is clear that a holistic view is needed, capable of addressing all relevant standards and covering both economic and safety issues. It is also clear that change can and should be driven from the whole-system viewpoint, aiming at delivery of the principles established through the Rail Technical Strategy process, taking the whole-system viewpoint. Different routes to defining that long-term configuration may be appropriate, but, when the optimal solutions are defined, their key interface elements should always be captured through the TSI or RGS standard – which can be achieved through the normal standards-change processes of the EU and RSSB.

5.18 Of equal importance to the actual standards is the perception that suppliers have of UK 'custom and practice' and the difficulty of gaining acceptance for innovative solutions. There is much anecdotal evidence that the UK is a very difficult market from this point of view and that this is a significant cause of the UK lagging well behind world-class standards of energy efficiency, train mass and infrastructure maintenance efficiency.

5.19 Key to solving this problem is the application of a consistent and objective approvals process for new equipment and trains. The application of Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS) and the Railways (Interoperability) Regulations 2006 should provide the opportunity to achieve this aim.

Economic/financial

Five-year funding cycle

5.20 Since long before privatisation, budget cycles have acted as a disincentive to long-term change. However, the Railways Act 2005 explicitly provides the opportunity to break out of this through the development of the HLOS and the associated 2007 Rail White Paper for the railway. The RTS, in support of the 2007 Rail White Paper is intended to provide long-term guidance for the procurement of assets and facilitate long-term change into investment policy decisions.

Investment appraisal and affordability

5.21 Technical and operational change must pass investment appraisal and affordability tests. This isn't easy, because the benefits of change are often beyond normal economic planning horizons or difficult to capture within the financial structure of the industry. A number of current programmes are showing how investment appraisal techniques considering planning horizons beyond 30 years to reflect second- and even third-generation renewal may help to overcome this. These programmes include:

- ERTMS is concentrating on delivering a low-cost signalling system in the medium term so that the system can deliver long-term flexibility and capacity benefits;

- For the IEP, whole-life system cost modelling is being used to evaluate targets and options for train mass and track quality to be set and linked to long-term benefits in energy efficiency, fuel cost and track damage reduction;
- The regenerative braking programme is overcoming perceived technical risks on the DC network, which could have made the programme unaffordable, by quantifying and progressively reducing the risk through the intelligent application of existing technology whilst continuing to underline the commercial benefits of success.

5.22 The particular problems and issues are different in each case, but the common themes are that the long term is kept in view, the benefits and costs assessed across the whole system and the whole life of the assets, and the obstacles to progress identified and overcome on a rational and pragmatic basis.

5.23 A challenge for the railway industry is to decide whether the current UK design philosophy does give the best overall whole-life system cost.

Costs and benefits fall to different parties

5.24 The structure of the privatised railway often results in costs and benefits falling to different parties. For example:

- The benefits of ERTMS fall largely to the DfT and Network Rail (infrastructure costs are reduced, system performance will rise), whereas the fitting of train-borne equipment will increase the costs of ownership and operation of trains, and potentially their exposure to failure;
- For regenerative braking, the position reverses, as the additional costs fall largely on Network Rail, whereas the benefits in terms of reduced energy consumption accrue to the train operators;
- Segregation of suburban metro operations presents service performance and capacity benefits for all operators, but can only be achieved to any significant extent by substantial infrastructure investment by Network Rail;
- Differentiation of regional routes presents potential cost savings to Network Rail, provided that this can be achieved without limiting the future scope of freight services.

5.25 Programme governance is central to programme success. Experience has shown that successful programmes are based on strong cross-industry governance and funding focused on delivering total industry benefit. It has become clear that, for major projects and programmes delivering substantial system-level change, Network Change is not always an effective commercial delivery mechanism, as it does not incentivise system-level cost-efficiency.

5.26 Some early success has been achieved through re-franchising specifications, but it is clear that access and performance regimes will need to be reviewed to reflect changes envisaged by the RTS as they are progressed. Performance regimes should be progressively renegotiated to reflect the changing 'achievability' to which each party is exposed.

Cultural

5.27 The railway is an inherently conservative organisation, where safe and successful day-to-day operation is paramount. Hence, changes are made on an incremental, try-it-and-see basis, as the railway consists of a range of old technologies that have historically been poorly documented. Furthermore, lessons learned from past projects and programmes have also been poorly documented. Making more radical changes such as are envisaged in this document will be difficult, particularly because there is relatively recent UK experience of major rail technology projects failing to deliver, as explained below.

5.28 A key issue in planning achievable change will be the involvement of all industry partners, aiming to generate a spirit of co-operation even where benefits at some stages of implementation may not be felt by all parties equally. Communication of the RTS to all members of the industry is already in hand. Network Rail has already briefed its 'Future Railway 2030' initiative, and similar initiatives are in progress within the train-operator community. The publication of this document should be a significant milestone in itself. The Technical Strategy Advisory Group needs to consider carefully the issues associated with culture change and how to overcome them.

Technological

Application of new technology

5.29 The UK railway industry has a culture of risk aversion and optimism in respect of innovative developments, particularly those with a technological basis. The Jubilee Line Extension and West Coast Train Control System (TCS) both tried to use advanced technologies (for the railway) to deliver major change within a major, time-bound project. In hindsight, both were probably over-optimistic and could probably have been successful given time, but time was not available and the project management team was forced to throw out the new technology relatively late in the project after considerable sums had been spent. In both cases this caused some degradation of the overall project outputs.

5.30 The lessons of these projects need to be remembered and acted upon – that technological development needs time, and that development needs to be driven forward very early in a programme life cycle to prove feasibility before a technology is committed to as the basis for a major change in output. Key elements of the RTS, particularly ERTMS, are being planned to avoid the risks of failure to deliver to a tight timescale in a critical area, by embarking on pilot schemes before aiming for full roll-out to critical routes.

Long asset life-cycle

5.31 Railway assets are traditionally robust and designed for a long life. The reason for this, in most cases, is that the traditional approach to railway design cannot tolerate single-point failures – there is no railway equivalent of a roadside wheel-change, and any major failure almost always has severe performance and safety implications. Also, railway assets get very heavy use – a railway carriage will serve several million passenger journeys in its life, probably two orders of magnitude higher than a car.

5.32 Long asset life can be a disadvantage in terms of adaptation to new technologies or to meet new challenges. The High Speed Trains designed 35 years ago are still with us and are fortunately designed fairly flexibly, so that new engine technologies, new interiors and various additional features have been easy to incorporate. However, some of the more modern trains are less flexible and will be a significant problem for the future in terms of adaptability. In some areas where developments are particularly fast-moving, such as communications, where obsolescence is rapid, longer-life assets may have to interface with several short-life assets during their lives.

Organisational/structural

5.33 In the industry structure created by the Railways Act 2005, the DfT and the Scottish Ministers are responsible for the long-term specification of outputs for the passenger railway. The DfT and the devolved administrations also control the strategy for franchising and the specification for individual franchises. A conclusion of the current work is that the DfT also needs to manage the specification of long-term needs for rolling stock for DfT franchises. However, the DfT does not have the necessary ethos or expertise to act as a system integrator or responsibility for specifying freight.

5.34 Network Rail has responsibility for the infrastructure and performance of the network. Network Rail has significant areas of technical and operational expertise and is developing the breadth of view to act as a system integrator. It is acting in this role quite successfully for the ERTMS programme and for Joint Performance Improvement teams. In the most successful areas it has been careful to involve the other parties to the railway system (TOCs, FOCs and RoSCos) as equal partners in the endeavour, and it is this model that should be used for the implementation of the aspects of the RTS with a major infrastructure engineering content.

5.35 The Freight and Passenger Train Operators have essential operational knowledge and a good breadth of technical knowledge to contribute. However, their interests are in the specific geographic and market sectors in which they operate. They should lead for customer-facing issues and systems and should be the key partner under Network Rail's lead for engineering systems.

Interoperability – the European dimension

5.36 The UK is committed to compliance with the European Safety and Interoperability Directives. The objectives of the European Commission in pursuing its interoperability initiative are to improve the integration and cohesion of the European network and to drive towards a common European market for railway assets, materials, components and processes. Although the primary interests of a single member state like the UK are in the development of a transport system to support its own economic and societal needs, there are substantial economic benefits and little practical conflict in implementing European Safety and Interoperability Directives, provided that member states are allowed to govern the rate of compliance.

5.37 In the UK context the benefits that can be derived from interoperability relate to product standardisation and a transparent process for product acceptance, with defined conformity assessment processes and criteria.

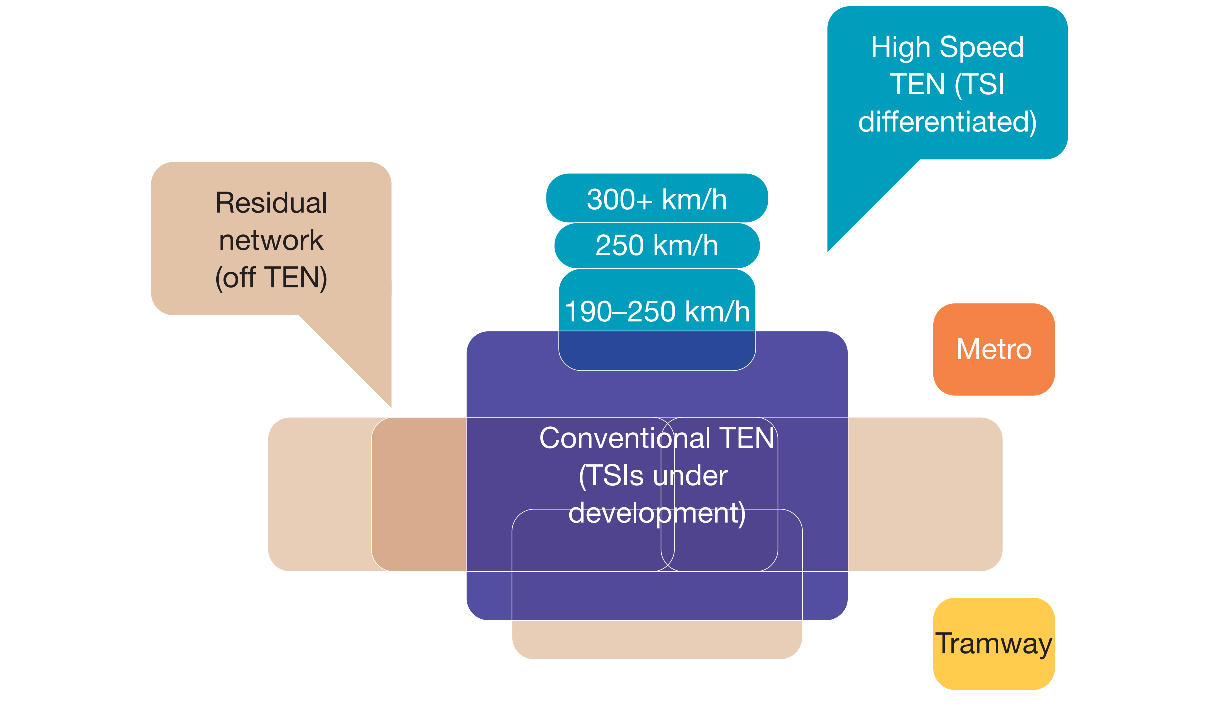
5.38 Interoperability is not an end in itself, but rather a mechanism that can contribute to the delivery of the RTS and the financial benefits of standardisation. Many of the concepts that form a part of the RTS are reflected in the TSIs, such as in-cab signalling and regenerative braking. The need for a differentiated railway system is recognised in the current approach to interoperability, and European research, influenced to no small extent by UK industry, is enhancing the clarity of this approach in a way that closely parallels our thinking. The framework excludes tramways and metro systems and divides the heavy rail network into three sections on the basis of the routes defined as part of the Trans-European Network (TEN) routes (Figure 5.3):

- High-speed lines where the high-speed TSI applies but is itself subdivided, depending on the operational speed;
- Conventional lines where the conventional TSIs under development will apply; and
- The rest of the lines that do not form part of the TEN routes and are not currently in scope of the TSIs (although they may be covered in future).

5.39 The differentiated structure in the interoperability framework is clearly rudimentary and reflects the fact that the first TSIs were developed in 2002. The provision of a technical strategy gives a clear target in the development of the TSIs and in future discussions concerning the expansion in scope of interoperability.

5.40 The considerable effort put by the UK Government and industry working together into the TSI development processes and interaction with the EC is beginning to have some effect. The UK industry participates through both the EIM and CER. The development of the RTS is itself proving influential and is a model that interests the EC. The EIM and CER are adopting similar approaches. The concept of a differentiated railway is taking hold and could prove key to the development of TSIs that include planned and consistent differentiation across European railways for different classes of traffic and infrastructure. If this is achieved, it will make adoption of the EC's plan for widening the scope of application of the directives much easier for all member states, because solutions that are suitable for all railway sectors can be developed. The UK should continue its close engagement with the European process.

Figure 5.3: **Application of interoperability under differentiation**



Research and innovation

5.41 Change to the railway can be supported and facilitated by encouraging innovation on the railways, facilitated through supporting and facilitating research aimed at validating and developing the long-term view and identifying innovative solutions that can support delivery. In the recent past, the industry's research track record has been improving from the low point it reached after privatisation. However, the railway is still a difficult environment for innovation. Part of the solution to this is to allow sufficient time for development to occur before an innovative idea is required in production. This may need an innovative approach to procurement and funding. Successful projects of this kind are often jointly funded between client and supplier.

5.42 A key next step following the publication of this document will be the development of a Railway Industry Research Strategy. This initiative will be taken forward by the DfT and the devolved administrations with their industry partners. It will take the 2007 Rail White Paper, including the RTS, as a baseline and will review the current priorities and arrangements for railway-related research to confirm that they are fit for purpose. The purpose of the Railway Industry Research Strategy will be to stimulate and co-ordinate rail research across the rail industry.

5.43 The development of the RTS has identified a number of gaps in knowledge, both of the technology implicit in the vision and of the trade-offs that will inform its further refinement. It is clear that the knowledge gaps identified in the RTS fit well into the six Advisory Group for Rail Research and Innovation (AGRRI) themes for future research, as follows:

Enhancing reliable capacity

5.44 Research initiatives in this area include:

- **High-reliability infrastructure:** This is an issue for both the multi-functional core and for high-density suburban areas. It is an area for Network Rail to address primarily;
- **High-reliability trains:** Targets need to be established for future train reliability, derived from an overall system model. The DfT should sponsor this work, with support from TOCs, RoSCos and Network Rail;
- **Effect of ERTMS on capacity:** Further work is needed to confirm the expected benefits on a system basis (i.e. moving beyond limited-scope studies to evaluation of whole routes and considering both incremental and radical change scenarios). The work should identify the new binding constraints that are exposed and propose mitigations;
- **Advisory speeds:** ERTMS does not currently include a system management/advisory speeds layer. A feasibility study for a UK solution is being started by RSSB. A particular issue is to quantify the energy and performance benefits of advisory speeds;
- **Effect of cab signalling on route knowledge requirements:** Research should consider what purposes route knowledge actually serves and how cab signalling will (and be specified to) fulfil those purposes;
- **Line-of-sight working:** Opportunities, human factors, risks and mitigations need to be reviewed at an outline level as a basis for development of the concept;
- **Freight (and other) train planning:** The current processes, procedural barriers and planning timescales need to be reviewed to preserve flexibility as demands on the network increase. Network Rail is doing work in this area;
- **Comparison of relative costs/benefits of train lengthening versus double-deck trains:** Network Rail has conducted a detailed analysis, and this needs to be developed to a point at which future options can be clarified.

Reducing specific cost of reliable infrastructure

5.45 Research initiatives in this area include:

- **Intelligent condition monitoring:** Feasible approaches and the potential link to maintenance programming and costs need are being developed by Network Rail and RIA in cooperation;
- **Detection of broken rails in the absence of track circuits:** There is an opportunity to make a positive step forward by designing a system that is actually intended to monitor infrastructure/rail integrity as a safety measure. Research is needed to identify the risks of eliminating track circuits and to set this against the costs and benefits of alternative measures;

- **'Graceful degradation':** This has been raised as a concept. Research is needed to explore the possible applications and implications at design level, and for operations standards and procedures;
- **Implications of 35-tonne axle-loads for infrastructure provision and maintenance, rolling stock types and wheel–rail interface:** An assessment of the full implications needs to be conducted;
- **Whole-life, whole-system costing:** RSSB is carrying out work in the vehicle area. Analysis of track and structures is being carried out by Network Rail. The two initiatives need to be cross-correlated so that whole-system results can be generated;
- **Differentiation:** There is a need for Network Rail to explore further and quantify cost savings from appropriate differentiation, particularly in relation to the presence or absence of freight traffic on rural and regional lines, to provide further evidence for the differentiated railway concept;
- **Reducing the risk and impact of trespassers onto railway infrastructure,** both deliberate (e.g. vandalism and suicide) and accidental (e.g. large-animal incursion).

Encouraging reduction in vehicle mass

5.46 Research initiatives in this area include:

- **Lightweight rolling stock:** Approaches, applications, opportunities, feasibility and implications for interaction with the track need to be further developed around the work already carried out by the System Interface Committees;
- **European 'LITE':** A European consortium led by RSSB has just submitted a proposal for the European 'LITE' project, which is aimed at reducing train mass;
- **Reductions in mass of equipment:** Further work needs to be initiated to realise reductions in the mass of cabling, interiors, fixtures and fittings.

The environmental case for rail

5.47 Research initiatives in this area include:

- **Baselining current environmental performance and setting targets for improvement:** RSSB is leading a programme of work under the auspices of the Sustainable Development Steering Group which is aimed at both baselining current environmental performance and setting targets for improvement;
- **Hybrid traction packages:** Initial research is being carried out by manufacturers, and some demonstrators are already in hand. A consortium is being formed, including ATOC, DfT, a RoSCo and Network Rail, to initiate a project in this area;

- **Biofuels:** ATOC is leading research in this area and has already established that there are no major technological barriers to the implementation of biofuels;
- **Air quality:** The UK is pressing for further European development work on the integration of NRMM IIIB compliant traction packages into railway locomotives and multiple units, to demonstrate that feasible solutions can be achieved and to ascertain the impact on fuel efficiency;
- **Energy metering:** ATOC and DfT are working together on an initiative to demonstrate the feasibility, costs and benefits of energy metering on trains, building on work already carried out in Germany and Scandinavia;
- **New forms of energy, e.g. fuel cell:** RSSB is engaged in the development of a project for possible inclusion in the EC Joint Technology Initiative (JTI);
- **Noise:** Research at European level is going on, both into the most economic means of reducing railway noise at source and into the perception of railway noise by those affected by it;
- **Impact of climate change on the railway:** Current work by RSSB and Network Rail needs to be expanded to identify all the critical vulnerabilities, the risk timescale and the mitigations needed, including changes to standards.

Improving the passenger experience

5.48 Research initiatives in this area include:

- **Communication with passengers by personal media:** As a basis for developing strategy, a view needs to be reached as to how widespread the various media will become (bearing in mind currently-unknown developments), of what types, and how their use will vary across regional/market/socio-economic sectors. What can be done to promote appropriate use? This is in effect a continuing need in view of fast-moving technological and market developments;
- **Integration of passenger data and information systems:** The ability of current and emerging technology needs to be explored, aiming to bring together a comprehensive database of passenger loadings in real time and to use this for passenger information, operational control and planning purposes.

T&RS – reducing cost and improving availability

5.49 Research initiatives in this area include:

- **Rational family of trains:** The concept needs to be developed in a realistic context, to confirm service groups potentially covered, benefits and any down-sides;

- **The European MODTRAIN project** is aimed at reduced life-cycle cost and improving availability;
- **Community rail:** Potential for innovative solutions for rolling stock and infrastructure needs to be explored in principle and outline as a basis for assessment of particular cases.

5.50 The development of the Research Strategy will confirm research themes to fill these gaps and map them to the improvement initiatives currently under way within industry and Government.

Next steps

5.51 This RTS sets out an engineering view of the railway as it could be in 30 years' time, taking account both of the impact of new technology on the railway and of the need to shift the balance of technology within the railway. Stakeholder support for this needs to be maintained through continuing engagement with the industry. The DfT role is recognised to be a combination of encouragement, selective financial assistance, and strategic direction and leadership.

5.52 Current research should be pursued, including initiatives by professional bodies investigating the concepts of lightweight, high-performance, low life-cycle cost rolling stock, and energy/capacity-optimised control systems. Table 5.3 provides a summary of the projects and initiatives currently supported by the DfT.

5.53 A major item of research associated with the RTS will be a financial and benefit analysis of applying appropriate differentiated standards to the identified network segments. Working with the rest of the industry, Network Rail is preparing to take the industry lead on this work.

5.54 The RTS also identifies issues for further research. It is expected that there will be a blend of research by RSSB and duty holders, as well as directly-commissioned specific research with initiatives from manufacturers and suppliers, which may be supported in part with matched or pump-priming funding.

Table 5.3: **Projects and initiatives currently supported by the DfT**

Project	Lead body	Outputs	Delivery
NFRIP Reliability Improvement Initiative	ATOC/industry	Improved reliability of existing train fleet	Current
ERTMS Programme – long-term product development	Network Rail (via Cross-Industry Team)	ERTMS work on advanced positioning	2007 on
Future signalling project – network optimisation	Network Rail (via V-TC&C SIC)	Specification for pilot implementation of network optimisation and driver advisory speeds	2007
Selective Door Operation Initiative	RSSB (via V-TC&C SIC)	National specification for Selective Door Operation	2007
Better timetabling	Network Rail and TOCs	Faster method of producing better-optimised timetables based on consistent network data	2007–09
Regenerative Braking Programme	Network Rail (via Cross-Industry Team)	Regenerative braking in use with all capable trains	2008
Intelligent Infrastructure Project	Network Rail	Improved reliability, better quality and reduced cost infrastructure	2008 on
ITSO/Smart Ticketing Programme	DfT/ATOC	ITSO rollout across heavy rail network Rollout of Customer Information Systems	2008 on
Tram–Train Project	Network Rail/ Northern	Evaluation of benefits of low-mass vehicle on rural lines	2009
ATOC Fuels Strategy	ATOC	Industry-agreed strategy for transition towards low-sulphur and biofuel	2009 on
Corporate Network Model	Network Rail	Consistent data model of network	2009 on
UK input into Innotrack	Network Rail	Innovative track forms with lower whole-life cost	2010
ATOC NRMM Compliance Programme	ATOC	Integration of low-emission diesel engines into UK diesel trains	2011 on
UK input into European Low Impact Trains Initiative	RSSB	Low-mass train designs	2012
Energy Metering Initiative	DfT/ATOC	Energy metering on electric fleet	2012 on
Next Generation Multiple Unit Projects	DfT/industry	New generation design for electric and diesel multiple-unit renewal	2012 on
Hybrid Traction Development	DfT/industry	Accelerated development of hybrid traction to support NG-DMU.	2012 on
Intercity Express Programme	DfT/industry	Intercity Express trains to replace HSTs and IC225s	2012–19
ERTMS Programme	Network Rail (via Cross-Industry Team)	ERTMS Level 2 on Cambrian, then migration to ECML, GWML	2015 onward
UK input into European Hydrogen Trains Initiative	RSSB	Integration of hydrogen fuel chain into railway trains and infrastructure	2020 to 2025

6. Conclusion

6.1 The RTS supports the DfT 2007 Rail White Paper and HLOS by:

- Developing an understanding of the implications of future needs;
- Creating a vision of the railway system, re-engineered to meet the challenge of the next 30 years;
- Understanding the barriers to change that need to be overcome;
- Identifying opportunities for affordable implementation of change;
- Identifying initiatives needed and action for Government and industry to take to deliver the long-term changes that the railway system needs.

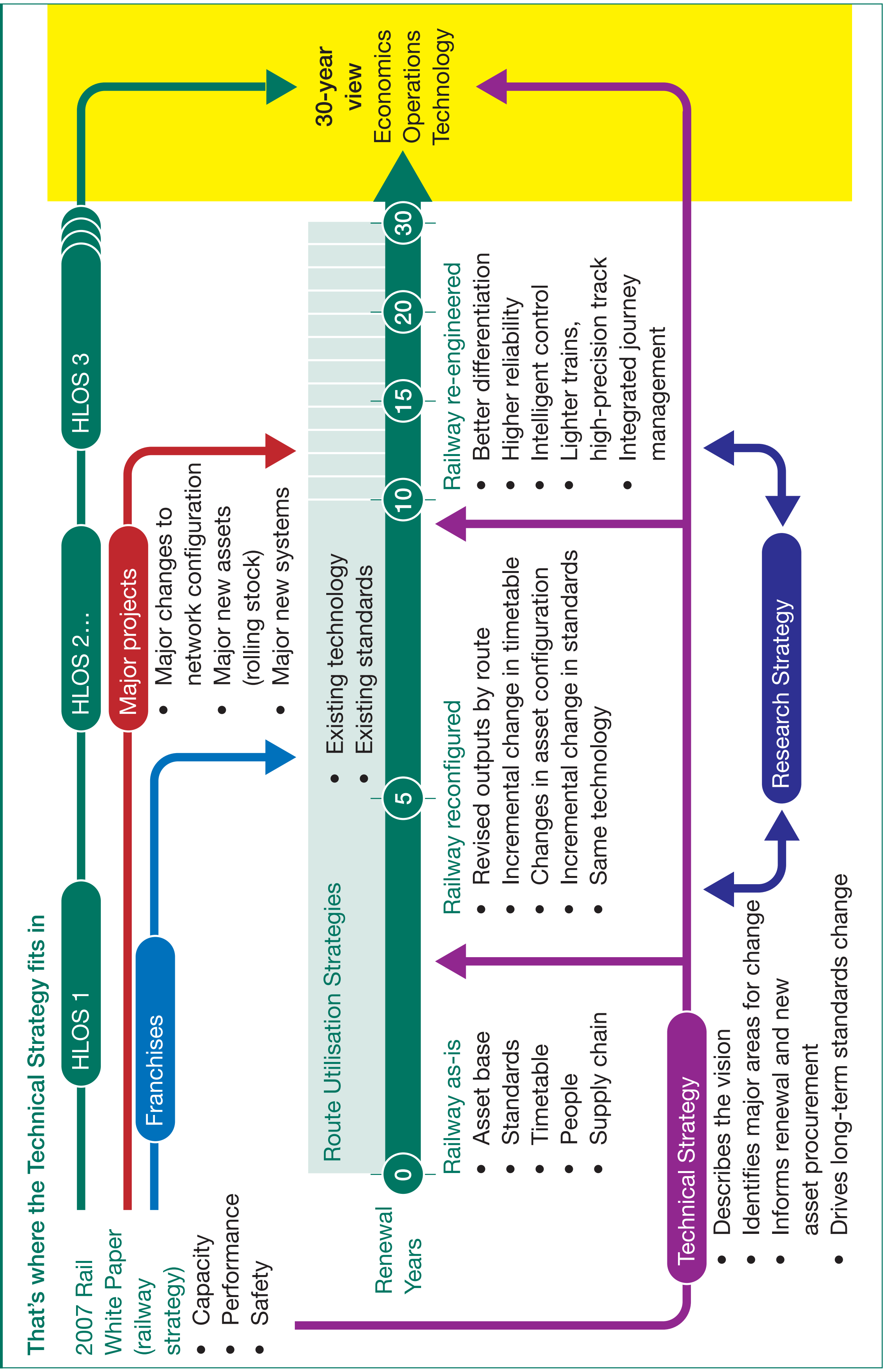
6.2 The key conclusions of the RTS demonstrate how current and emerging technologies can be applied to deliver the capacity required from the railway network, whilst improving sustainability and meeting affordability criteria:

- The capacity of the rail network can continue to be enhanced through conventional incremental upgrades, but to exploit the infrastructure to the maximum, advanced signalling systems such as ERTMS need to be deployed in conjunction with high-reliability trains, infrastructure and precision operations, and control of train movement;
- Rail-transport carbon emissions can be improved in the short term by better housekeeping and implementation of regenerative braking. In the longer term, lighter rolling stock using new technologies for energy storage, energy metering and management and advanced movement management systems will further enhance the lead position of rail;
- Cost efficiency will be achieved through a whole-life, whole-system costing approach, application of standards for assets and operations that are appropriate to the type and level of use made of each segment of the network, the application of sustainable operational limits to the track-to-train interface, the reduction in fixed and track-based signalling equipment following roll-out of ERTMS Level 2 and its subsequent developments, and greater use of standardised or commercial off-the-shelf equipment.

6.3 It will equally be important to meet changing passenger expectations by improving the attractiveness of the rail mode compared with less environmentally-friendly competition. This will be promoted through exploitation of communications technology and an integrated approach to the overall journey experience.

6.4 The DfT will continue to engage with all industry partners and stakeholders to encourage and support research, encourage alignment of incentives through the ORR and facilitate cross-industry programmes and projects that will deliver long-term change (Figure 6.1).

Figure 6.1: **The 30-year vision incorporated in the RTS**



7. Acknowledgements

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- ATOC Engineering Forum
- EWS Ltd
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- Institution of Engineering and Technology
- Institution of Railway Operators
- Institution of Mechanical Engineers
- Institution of Civil Engineers
- Institution of Railway Signalling Engineers
- National Task Force
- Network Rail
- Office of Rail Regulation
- Passenger Train Operators
- Rail Freight Group
- Rail Safety and Standards Board
- Railway Engineering Forum
- Rail Freight Operations Managers Group
- RIA Consultants Group
- RIA Electrification Technical Interest Group
- RIA Signalling and Telecommunications Technical Interest Group
- RIA Traction and Rolling Stock Technical Interest Group
- RoSCo Technical Liaison Group
- The five System Interface Committees
- The six Standards Committees
- Transport for London
- Transport Scotland
- Welsh Assembly Government

8. Glossary

ATP	Automatic Train Protection, a control system that supervises driver control of train speed and automatically initiates braking when necessary to prevent trains exceeding safe speed and movement authority.
ATO	Automatic Train Operation, control of train propulsion and braking without intervention of a driver. The ability to control train movement consistently to the limits of the system can have significant capacity benefits and eliminates dependency on route knowledge.
axle-counter	An alternative to track circuits for track-based train detection.
bi-directional operation	Working of trains in either direction over a single line of rails under control of the signalling system.
cab signalling	Display of signal indications or other movement authorities within the cab, to supplement or replace line-side signals.
dwell times	The interval between a train coming to a stand in a station and restarting, encompassing passenger boarding and alighting, door operations and despatch activities.
ERTMS	European Rail Traffic Management System.
fail-safe	The principle whereby signalling and other safety-critical equipment, if it becomes defective, defaults to prevent movement of trains.
FOC	Freight Operating Company.
Freight RUS	Network Rail's Route Utilisation Strategy specifically considering freight services throughout the UK as opposed to all services on a particular route.
GC	'Gauge C', the most generous kinematic profile given in the Infrastructure TSIs.
GPRS	General Packet Radio Service – a form of packaging data for transmission across a digital communication system.
grade-separation	Carrying the line of rails for one flow of traffic over or under the line of rails for a conflicting flow, thus allowing traffic to flow without interruption on both lines.
GSM-R	Global System for Mobile communications – Railways.
headway	The minimum interval between trains on the same line in the same direction that is allowed by the signalling system.
high-speed trains	InterCity 125 trains introduced by British Rail in the 1970s.

hybrids	Hybrid technology would combine a diesel engine/generator and batteries to produce a more efficient means of powering a train, using electric power to move the train at low speeds, with the engine cutting in to provide extra power for acceleration. When the train brakes, its kinetic energy would be converted into electrical energy to recharge the batteries.
line capacity	The frequency, normally measured in trains per hour, with which trains of the same characteristics can flow on one line in isolation, under defined conditions of station stops and train speed.
line-of-sight working	Regulation of train speed without fixed or cab signals on the basis of the driver's view of the line ahead and his/her knowledge of the braking capability of the train should an obstruction or another train be in view.
movement authority	Information given by the signalling system as to how far a train can proceed.
network capacity	The number of trains that can operate on a rail network in a given time period, reflecting factors such as junction interactions, terminal capabilities, the mix of train speeds and the number and order of trains of different speed capabilities and stopping patterns called for by commercial or regulatory requirements. The Institution of Railway Operators' definition of network capacity is: *The number of trains that can be incorporated into a timetable that is conflict-free, commercially attractive, compliant with regulatory requirements, and can be operated whilst meeting agreed performance targets in the face of anticipated levels of primary delay.*
network modelling framework	A comprehensive set of models developed by the industry under the leadership of DfT, which enables the impact of changes to the railway network and services operated on cost, performance, safety and crowding to be predicted.
passenger capacity	The number of passengers that can be accommodated in a passenger vehicle. The Network Modelling Framework defines the capacity of a vehicle as the number of seats plus the number of passengers who can be accommodated in the available standing space at a given allocation of space per standing passenger. The total capacity of the railway system to carry passengers is then the resultant of the passenger capacity of each vehicle, the number of vehicles on each train and the network capacity (q.v.).
path	A possible schedule for a train along its route that reflects the achievable sectional running times and does not infringe permitted planning separations from schedules of other trains.

performance time	A deliberate extension to planned sectional running times in a trip schedule made specifically to allow recovery from late running.
platform stepping distance	The gap between the platform and the train, both horizontal and vertical, and influenced by factors such as rolling-stock gauge clearance, platform design and curvature, location of doorways with respect to bogies' centres, and super-elevation of track in curved platforms.
possessions	Temporary dedication of a section of the network to engineering activities, requiring normal train movements on that section to be suspended
primary delay	Delay to trains arising directly from an incident such as a technical failure or line blockage through external cause, as opposed to secondary delay (q.v.).
predictive route algorithm	Operational decision support tools that work at a system level and focus upon railway operation from a junction management rather than route-setting railway perspective. it works in real time and reflects the characteristics of the infrastructure and rolling stock, with a view to optimising operations for minimum delay, energy use or other selected parameter.
RA	An RA number is given to individual items and types of rolling stock to reflect the combination of axle load and vehicle dynamics that the rolling stock imposes, and that the route can accept. For a vehicle to be permitted to run (without special authority) over a route, the RA number for the route must be equal to or greater than that for the vehicle.
regenerative braking	A way of slowing an electrically-powered train by using the motors as brakes. Instead of the surplus energy of the vehicle being wasted as unwanted heat, the motors act as generators and return it as electricity into the supply rail or overhead wire.
reoccupation times	The minimum interval allowed by the signalling system between one train starting from a platform after its dwell time and the next arriving, without receiving signal aspects or movement authorities that are more restrictive than the need to stop in the platform.
RFID	Radio Frequency Identification.
robustness	The ability of a timetable and network to experience primary delay (q.v.) without this translating into secondary delay (q.v.).
ROGS	Railway and Other Guided Transport Systems (Safety) Regulations 2006.
RoSCos	Rolling Stock Companies, owning rolling stock and leasing it to TOCs (q.v.).

rules of the plan	The operational requirements around which a timetable is to be based, setting out minimum acceptable values for factors such as sectional running times, headways, turnaround times, permitted train lengths in stations.
secondary delay	Delay caused by one train to another, remote from the location of an incident, which itself would not have delayed the other train.
signal sighting	The ability of the driver of an approaching train to appreciate the aspect of a line-side signal, with respect to train speed, line curvature and gradient or obstacles such as structures or vegetation, and to environmental factors such as sunlight.
slab track	Permanent Way consisting of rails secured to or cast into a continuous concrete slab instead of intermittent sleepers.
super-capacitors	An alternative to batteries for on-board energy storage, able to charge more quickly, and thus potentially capturing a greater proportion of regenerated energy.
switches	Movable rails that direct trains from one line to another at junctions.
system capacity	The total capacity of the railway system to carry passengers or freight. This is the resultant of the passenger capacity (q.v.) of each vehicle or payload of each freight wagon, the number of vehicles on each train and the network capacity (q.v.) or that part of it allocated to either passenger or freight traffic. Unless line, network or passenger capacity is specified, capacity can be understood to denote system capacity.
TOC	Train Operating Company.
track brakes	Emergency brakes acting directly on the rails rather than through the wheels of a vehicle.
track-circuit	An electric current flowing in the running rails of a defined section of track, which confirms to the signalling system that the section is not occupied by a train.
train detection	The function of the signalling system that identifies the location on the network of a train so as to ensure physical separation from other trains.
tram–train	Multi-functional vehicle capable of operating on heavy rail networks but also on light rail networks possibly featuring street running.
TSI	Technical Standard for Interoperability.
W6a, W9, W10, W12, etc.	Defined standards for dimensions of line-side structures and freight vehicles.
white space	Unused opportunities in the timetable for train paths (q.v.) and available for short-term requirements, or deliberately left unused to promote robustness (q.v.).

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