September 2011

Network RUS

Passenger Rolling Stock

Contents

Foreword

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I am pleased to present the latest output from the Network Route Utilisation Strategy workstream: a strategy for passenger rolling stock procurement and associated infrastructure planning. The document has been produced in conjunction with train operators, representatives of customers, manufacturers and rolling stock owning groups as well as the Department for Transport, Transport Scotland, the Welsh Government, The Passenger Transport Executive Group and Transport for London.

Under whichever structure the British railway network has been organised, the alignment of passenger rolling stock procurement with a) customer needs and expectations and b) the characteristics of the railway infrastructure has always been complex. The historical development of the railway saw different track and loading gauges, different platform heights and lengths, different signalling systems, different braking systems, different types of electrification, different lengths of vehicles, different policies on maximum gradients (affecting train weights and speeds), different interior layouts of rolling stock, different operating practices, and so on and so forth.

Whilst, over the years, many attempts have been made to homogenise both rolling and fixed assets, only seldom since the original construction of lines have the two been considered together; and almost never across the network as a whole. This reflects, in part, the differing life expectancies of the various assets. As a result, there exists a plethora of varying types of rolling stock, to a degree incompatible with each other, and often constrained to discrete parts of the network. This in turn has resulted in considerable inefficiencies in rolling stock procurement, as fleets, recently in particular, have tended to be ordered in small, bespoke batches.

Extreme complexity, however, is no reason for inaction, inertia or quiescence. The need safely to drive inefficient costs out of the industry is paramount. This strategy concludes that, over the next two generations of new rolling stock, potentially hundreds of millions of pounds could be saved.

The conclusions of this study are consistent with the findings of the recently published Rail Value for Money Study by Sir Roy McNulty. The scale of the opportunity in this area is clear and we are keen to work with the rest of the industry to help define the best way to realise this opportunity. Together the industry needs to help inform government decisions about what it wants from the railway and, once specified, it needs the flexibility to deliver these requirements in the most efficient way.

To achieve this will require the procurement of rolling stock to be fully aligned with planning the capability of the infrastructure across the entire network. Approaches which give low priority to whole-life whole-industry costs, to operational flexibility, or to the interface between wheel and rail, are unlikely to prove efficient. But it is also critical that we exploit the potential for innovation through flexible industry processes.

Going forward, we seek to work with our industry partners and, through engagement with the Rail Delivery Group, to take on the challenge of driving out unnecessary cost from the planning of future rolling stock, together with the infrastructure to accommodate it, to the ultimate benefit of passenger and taxpayer alike.

Paul Plummer
Group Strategy Director

Executive summary

Passenger rolling stock costs are currently in the order of £1.8 billion per year. This represents around 15 per cent of the annual costs of operating the railway as a whole. The Network Route Utilisation Strategy (RUS): Passenger Rolling Stock document has taken a long term view of future passenger rolling stock and the infrastructure it operates over to establish whether there is potential to plan the railway more efficiently.

Other than the Freight RUS, which was established in 2007, the Network RUS is the only RUS which covers the entire network. Its network-wide perspective, supported by a stakeholder group with network-wide expertise, enables the development of a consistent approach to issues which underpin the development of the network. It is intended that the outputs of this strategy will be used in subsequent industry planning and inform the approaches taken by franchise bidders and manufacturers in future procurements, thereby ensuring that the key issues will be dealt with consistently.

The Network RUS is overseen by a Stakeholder Management Group consisting of Network Rail, Department for Transport (DfT), Transport Scotland, the Welsh Government, Transport for London (TfL), the Passenger Transport Executive Group (PTEG), the Association of Train Operating Companies (ATOC), freight operating companies, Passenger Focus, London TravelWatch, the Rolling Stock Companies (ROSCOs), the Rail Freight Group and the Freight Transport Association. The Office of Rail Regulation (ORR) attends the Stakeholder Management Group meetings as an observer. The Passenger Rolling Stock workstream was developed by a Working Group consisting of Network Rail, ATOC, DfT, Transport Scotland, Passenger Focus, PTEG, ROSCOs, TfL and The Railway Industry Association (RIA) (representing a number of train manufacturers), again with the ORR as observer.

Despite the unique role of the Network RUS in the RUS programme, the approach followed is similar to other RUSs by considering the current situation, drivers of change, gaps and options to address the gaps. It has considered stakeholder aspirations, including those who use, fund, procure, operate and build rolling stock.

The passenger network is currently operated by more than 12,000 vehicles, divided into 64 different rolling stock classes. There have been more than 5,000 new vehicles introduced since 1996, and substantial new orders for long distance high speed trains, Thameslink and Crossrail vehicles are expected in the near future.

A large proportion of the fleet, however, is considerably older. Historically the railway has considered commercial asset life as a nominal 30 years for diesel trains, and 35 years for electric trains. In theory, over the next ten years a quarter of the fleet would need to be replaced on this basis. Recent technical research suggests that the life of some rolling stock can be extended considerably. Where this is possible, meets customer expectations and makes sense commercially, life extension of rolling stock may be a better whole life cost solution than purchasing new rolling stock in the short term. However, even if the life of much of the stock were to be extended for five years, 12 per cent of the fleet would still need to be replaced in that period.

In addition, if the rail industry were to accommodate the forecast growth in usage, it would require additional vehicles. Given that the cost of new vehicles is reported to be up to £1.6 million for a standard specification and approaching £2 million for a higher specification, the search for better value for money solutions is an important and pressing one.

The strategy concentrates on the opportunities for efficiencies which arise when purchasing new rolling stock. It addresses the advantages of standardisation of both trains and infrastructure and the need for a whole industry approach. It considers how planning the rolling stock and infrastructure together can enable the network to become more inter-operable to enable rolling stock which serves a particular market sector to go anywhere on the network it is required.

The key principles used to develop the strategy are to:

a) move towards a whole industry whole life cost approach in which rolling stock and infrastructure are planned together

b) exploit the economies of scale in procurement wherever feasible

c) meet the needs of each market sector when ordering rolling stock

d) consider those infrastructure works needed to allow the rolling stock to be inter-operable within the market sector it serves

e) consider the phasing of future rolling stock procurement and infrastructure planning, including the potential for extending the life of existing vehicles.

The strategy is purposely kept at a high level to identify the principles of what can be achieved. It avoids the detailed specification of trains, other than to identify the key needs of each market, highlighting key economies of scale which help to reduce production costs and those physical characteristics of the trains and infrastructure which enable rolling stock to be more inter-operable across the network. It is anticipated that train operating companies would play a key role in the detailed specification of trains, giving them the ability to be innovative in the product that they bring to the market.

Information provided by a number of train manufacturers through RIA, suggests that there are considerable economies of scale to be had from reducing the variety of different rolling stock designs. Based on this information, it is estimated that in the region of £75 million or eight per cent of the average procurement cost is spent on non-recurring costs including research and development of bespoke rolling stock.

Whilst a reduction in the number of train types is attractive in theory, it only becomes attractive in practice if the train types procured match the needs of the market and can operate freely on the network where they are required. With this in mind, the RUS Working Group considered the passenger and operational needs of the main market sectors and concluded that there was a need for five broad categories of train:

- **Type 1 and Type 2:** long distance high speed with a tilt variant
- **Type 3:** interurban and outer suburban
- **Type 4:** regional and rural
- **Type 5:** inner suburban.

Passenger requirements were considered throughout. It was recognised that other catagories could evolve over time if passenger requirements change or if other types (such as tram train) are proven to be better value for money.

The strategy then continues to identify the infrastructure works that are required to enable inter-operability within a market sector. It looks at where trains of each sector might be expected to operate. A map of the network is presented which shows that it is a complex picture – with many lines being used by more than one market sector and by freight services. Having identified the routes on which the rolling stock will operate, it considers what gauge, platform length, route availability and platform stepping distance issues would need to be considered to ensure inter-operability.

Freight gauges and electrification clearances will remain an important determinant of infrastructure gauge. This is because freight operates over much of the network and the electrification strategy has established a case for further electrification of the network. However, optimising passenger rolling stock vehicle dimensions will also need to be considered.

The strategy recommends that procurers give further consideration to the high level features of passenger vehicles which would meet the aspirations of each market sector and operate at a gauge which would enable inter-operability between routes. This would enable trains which serve a particular market to go where required unimpeded by infrastructure constraints. The strategy takes the current procurement processes for the Intercity Express Programme (IEP), Thameslink and Crossrail as a given starting point and concentrates on the remainder of the network.

It proposes that the rail industry develops a series of standard kinematic envelopes from an understanding of both the passenger and train operator needs, as well as the infrastructure capability. It is proposed that the industry works together to produce a series of national passenger gauges built around the recommended vehicle lengths. The analysis in the strategy suggests that a 23 metre vehicle could be deployed across a considerable amount of the network with relatively low costs for infrastructure interventions. It is envisaged that a 20 metre variant might be required for those parts of the network where a business case for 23 metre vehicles could not be made.

Finally, the document considers the phasing of the strategy. The manufacturers represented by RIA suggest that up to 20 per cent of procurement costs could have been saved between 1988 and 2010 if there had been continuity of orders. This would imply that there would be considerable advantages to phasing the implementation to meet a smooth profile of orders. A completely smooth procurement profile, however, is unlikely in practice because:

- budgets in any financial year will be determined by affordability
- rolling stock procurement often occurs in conjunction with other events such as franchise replacement or infrastructure upgrades such as Thameslink and Crossrail.

In a commercial environment, there is inevitably tension between the manufacturers aspirations of continuity of orders and procurers aspiration to maintain competitive tension between suppliers, to reduce costs. Each procurement arrangement will be a commercial deal. Nonetheless, it is recommended that the cost savings of continuity of production are considered by procurers as part of this process.

The strategy assumes that rolling stock manufacturers will compete for each contract and that the outcome might be that there is more than one supplier in each category.

Provision of adequate rolling stock is a key part of the bidding and operation of a franchise. Refranchising represents an important instrument for influencing the fleet size, timing and pattern of procuring future rolling stock. It is therefore recommended that the benefits of planning rolling stock and infrastructure together and the potential economies of scale in rolling stock procurement are considered at an early stage in the refranchising process. Similarly they should be considered when planning major infrastructure enhancement programmes.

The detailed requirements for the development of the infrastructure will be included in Network Rail's Route Specifications to ensure that they are considered in the detailed plans for the infrastructure.

This strategy builds on the Network RUS: Electrification strategy which identified those parts of the network which are appropriate candidates for future electrification and, conversely, those which are unlikely to be future candidates. It is recommended that opportunities for efficiencies in rolling stock procurement or life extension are considered alongside opportunities for electrification and, where appropriate, the services are optimised to maximise the benefits.

It is further recommended that a clearance strategy is adopted whereby the gauging work required to accommodate trains of each type is carried out at the same time as other gauging or renewal activity on the route whenever the opportunity arises. As a guiding principle, a structure should only be re-built once. If the structure needs to be gauge cleared for freight or electrification (in line with the Strategic Freight Network or the Network RUS: Electrification strategy), this work should be done at the same time, ensuring that the new design is consistent with all three strategies.

1. Background

1.1 Context

Following the Rail Review in 2004 and the Railways Act 2005, the Office of Rail Regulation (ORR) modified Network Rail's Licence in June 2005 (as further amended, in April 2009) to require the establishment of Route Utilisation Strategies (RUSs) across the network. Simultaneously, the ORR published guidelines on RUSs. A RUS is defined in condition 1 of the revised licence, in respect of the network or part of the network, as a strategy which will promote the route utilisation objective.

The route utilisation objective is defined as:

'the efficient and effective use and development of the capacity available, consistent with funding that is, or is likely to become, available.'

Extract from ORR Guidelines on Route Utilisation Strategies, April 2009

The ORR Guidelines explain how Network Rail should consider the position of the railway funding authorities, their statements, key outputs and any options they would wish to see tested. Such strategies should:

'enable Network Rail and persons providing services relating to railways to better plan their businesses, and funders better plan their activities.'

Extract from ORR Guidelines on Route Utilisation Strategies, April 2009

The process is designed to be inclusive. Joint working is encouraged between industry parties, who share ownership of each RUS through its industry Stakeholder Management Group.

RUSs occupy a particular place in the planning activity for the rail industry. They use available input from Government Policy documents such as the Department for Transport's Rail White Papers and Rail Technical Strategy, the Wales Rail Planning Assessment, and Transport Scotland's publication, Scotland's Railways. The recommendations of a RUS and the evidence of relationships and dependencies revealed in the work to reach them in turn form an input to decisions made by industry funders and suppliers on issues such as franchise specifications, investment plans or the High Level Output Specifications (HLOS).

Network Rail will take account of the recommendations from RUSs when carrying out its activities and the ORR will take account of established RUSs when exercising its functions.

1.2 Document structure

This document starts by describing, in **Chapter 2**, the role of the Network RUS in the RUS programme. It describes the scope of the Network RUS: Passenger Rolling Stock including the key issues which it will consider and the time horizon which it addresses. It outlines the policy context and the relationship between the RUS and related policy issues which are being considered concurrently by our funders.

Chapter 3 presents the baseline for this study. It describes the current passenger rolling stock fleet, the market sectors which they serve and the needs of passengers.

In **Chapter 4** the drivers for change are set out, and in **Chapter 5** the gaps relating to passenger rolling stock and the infrastructure are described.

Chapter 6 outlines the options which were proposed by the RUS Working Group to bridge the gaps identified. **Chapter 7** describes the responses to the consultation and **Chapter 8** outlines the strategy.

Finally, **Chapter 9** describes the next steps that will be undertaken following the publication of the document.

2. Scope and planning context

2.1 The role of the Network RUS within the RUS programme

Other than the Freight Route Utilisation Strategy (RUS) which was established in May 2007, the Network RUS is the only RUS which covers the entire network. Its network-wide perspective – supported by a stakeholder group with network-wide expertise – enables the development of a consistent approach on a number of key strategic issues which underpin the future development of the network.

The unique nature of the Network RUS, the broad range of its stakeholders and its inevitable interface with other key strategic workstreams make it somewhat different from the geographical RUSs. As a result, the Network RUS team has developed a meeting structure, industry consultation and programme to ensure that it too produces key, timely and thoroughly consulted deliverables.

There are currently five Working Groups of the Network RUS, some of which have already been published and been established with the ORR:

- **Working Group 1** – Scenarios and long distance forecasts (published and established)
- **Working Group 2** – Stations (published August 2011)
- **Working Group 3** – Passenger rolling stock and depots
- **Working Group 4** – Electrification (published and established)
- **Working Group 5** – Alternative solutions to efficiently delivering passenger demand (work commenced 2010).

2.2 Network-wide perspective

The Network RUS enables strategies to be developed by the industry, its funders, users and suppliers which are underpinned by a network wide perspective of rail planning. The development of such strategies, which will be used in subsequent industry planning, thereby ensure that key issues are dealt with consistently throughout the RUS programme.

It enables strategies to be developed which by their very nature cross RUS boundaries (eg the development of future rolling stock families and electrification) or benefit from the development of strategies for best practice for different sectors of the railway.

2.3 Organisation: Stakeholder Management Group and Working Group

In common with all other RUSs, the Network RUS is overseen by a Stakeholder Management Group (SMG). The SMG is chaired by Network Rail. It draws its members from:

- Association of Train Operating Companies (ATOC)
- Department for Transport (DfT)
- Freight Operating Companies
- Freight Transport Association
- London TravelWatch
- Passenger Focus
- Passenger Transport Executive Group (PTEG)
- Rail Freight Group
- Rolling Stock Companies (ROSCOs)
- Transport for London (TfL)
- Transport Scotland
- Welsh Government
- Office of Rail Regulation (ORR) in the capacity of observer.

The majority of the work and detailed stakeholder consultation, however, is carried out within Working Groups which have been formed to steer each of the Network RUS workstreams. The Working Groups manage each workstream as if it were a 'mini RUS.' The groups vary in size but are all small enough to ensure effective levels of engagement between the participants. However, given that each is composed of individuals with relevant expertise or strategic locus for the specific 'mini RUS' subject matter, they play an important role in recommending a strategy for endorsement by the SMG.

The SMG is the endorsement body for the outputs of the individual workstreams. Its agenda concentrates on key decisions – from endorsement of the Working Group remits to approval of key documents and ultimately the resulting strategy. If the SMG has comments or questions on papers, these would be referred back to the Working Group which contains each of the SMG organisations' specialist representatives.

2.4 Network RUS workstreams

The first meeting of the SMG identified those elements of strategy which it wished to include in the Network RUS. A Working Group was formed to take forward each chosen element of strategy. The Passenger Rolling Stock Working Group consists of members of the following organisations:

- ATOC
- DfT
- Network Rail
- Passenger Focus
- PTEG
- Railway Industry Association (RIA)
- ROSCOs
- TfL
- Transport Scotland
- Welsh Government
- ORR (in the capacity of observer).

2.5 Time horizon

The Network RUS takes a thirty year perspective to be consistent with the long term views of transport planning taken by UK Governments in their recent strategy documents, notably the DfT's Rail White Paper (2007) and Transport Scotland's Strategic Transport Project Review (2008).

2.6 Planning context

The DfT published its 'Delivering a sustainable railway' White Paper in July 2007. It provided a vision for the next 30 years for rail planning in England and Wales. Over this period, it envisaged a doubling of passenger numbers and of freight transported by rail. It envisaged a railway which would expand to meet the increased demand, reduce its environmental impact, and meet increasing customer expectations, whilst at the same time continuing to improve its cost efficiency.

The White Paper stated the case for future rolling stock investments and suggested that a fleet with an average age of 15 years created the right balance between customer and environmental considerations. It said that:

> **'Investment in new rolling stock is an important part of improving the customer environment.'**
>
> Extract from 'Delivering a Sustainable Railway' White Paper, 2007

The DfT's 'Rail Technical Strategy' was produced to accompany the White Paper. The document brings together a long-term vision of the railway which optimises the use of existing technology and predicts the impact of new technology.

The Rail Technical Strategy identifies a number of long term themes for change:

- optimised track-train interface
- high reliability, high capacity
- simple, flexible, precise control system
- optimised traction power and energy
- an integrated view of safety, security and health
- improved passenger focus
- rationalisation and standardisation of assets
- differentiated technical principals and standards.

The most directly relevant theme to this strategy is the optimisation of the network. This highlights that the railway is multifunctional and is required to serve the passenger market sectors as well as freight. The Rail Technical Strategy envisages a network that can be considered in the following segments:

- a 'multifunctional core' which is capable of carrying any kind of traffic
- a 'suburban metro' railway, which is optimised to provide high capacity
- a 'regional' railway, which is optimised for lower cost.

A number of other themes, however, are relevant, notably the optimisation of the track-train interface theme which makes reference to a vision of light but strong rolling stock and the 'high reliability, high capacity' theme.

The Rail Technical Strategy expresses that customer needs and expectations will change substantially over a 30 year period. It says:

> **'what is accepted now in terms of service quality is unlikely to be acceptable in thirty years.'**
>
> Extract from the DFT 'Rail Technical Strategy,' 2007

The Rail Technical Strategy asserts that the average passenger will change. They will become taller, wider and older than now. The future of the railway sees a transport sector that needs to accommodate high demand.

2.7 Scope of the Network RUS: Passenger Rolling Stock Strategy

The strategy takes a long term view of future passenger rolling stock and the infrastructure it will operate over to establish whether there may be potential to plan the railway more efficiently. Its development has considered stakeholder aspirations, including those who fund, procure, operate and build the rolling stock.

The strategy seeks to enhance the understanding of the issues regarding rolling stock passenger needs and the infrastructure required to accommodate them. It presents a high level strategy but, given the uncertainties about affordability and on-going discussions around franchising reform, it does not give a detailed picture of implementation. Specific aims agreed by the SMG were:

- to determine the baseline which will include the characteristics and disposition of rolling stock that currently operates on the network. The baseline will include maps showing the routes on which existing rolling stock (suitably grouped) currently runs
- to develop an understanding of the generic passenger requirements relating to rolling stock according to different market sectors (eg long distance and suburban)
- to use the evolving Strategic Freight Network Strategy to understand synergies with the requirements for freight
- to identify the drivers of change that impact upon passenger rolling stock design and usage across the network. These drivers may arise from changes in the passenger needs of each market sector and a combination of operational, environmental (eg carbon), legislative, infrastructure and technology driven requirements. It will also take cognisance of the established Network RUS electrification strategy
- to identify options for rolling stock and infrastructure, in light of the possible technical and environmental issues faced by the rail industry
- to evaluate future rolling stock / infrastructure options using a whole industry, whole life cost approach
- to identify a longer term rolling stock and related infrastructure 'specification' for each route. A case study will initially be used to test and refine the methodology.

The business case will be evaluated against a base of do-nothing, and appraised according to current DfT guidelines. A preliminary evaluation of schemes will establish a priority list for appraisal.

As mentioned in **Chapter 1**, the RUS outcome will help inform the Department for Transport (DfT) and Transport Scotland's High Level Output specifications.

This strategy takes into account relevant findings from a number of on-going workstreams, notably the DfT's Technical Strategy Leadership Group (TSLG), and the on-going technical and strategic thinking underlying the development of a new Intercity Express train have been recognised.

3. Baseline

3.1 Current vehicles over the network

In Great Britain, most passenger rolling stock is owned by Rolling Stock Companies (ROSCOs) and leased to passenger Train Operating Companies (TOCs). Passenger rolling stock falls into three broad types: locomotive hauled vehicles, electric multiple units (EMUs) and diesel multiple units (DMUs). Multiple unit sets are self-contained for power, with a driving position at each end. Within each of these types there are individual classes, typically manufactured over a period of one to four years. Units within a class share characteristics of vehicle length, traction arrangements and door position. It is possible to couple together units of the same class, and in some cases units of different classes can couple with each other, in order to create a longer train under the control of one driver.

The size and disposition of the rolling stock fleet varies over time, with the withdrawal of older vehicles, and the introduction of new vehicles. The allocation of vehicles within and between TOCs also changes over time. The baselining information presented here provides a snapshot at December 2010. It includes vehicles leased by TOCs, as well as vehicles which are potentially useable and in store.

3.1.1 Passenger rolling stock fleet size

As of December 2010, the total rolling stock fleet comprised over 12,100 passenger carrying vehicles, made up of approximately 1,200 locomotive hauled vehicles, 8,000 vehicles in electric multiple units and 2,900 vehicles in diesel multiple units. The predominant type of vehicle is the EMU, which makes up about 66 per cent of the fleet, with DMUs comprising about 23 per cent and locomotive hauled vehicles about 10 per cent. The number of passenger vehicles, and, in the case of multiple units, the number of units, in each class, are shown in **Tables 3.1, 3.2 & 3.3.**

Table 3.1 – Passenger locomotive hauled vehicles

Class	Number of coaches
Mk2 coach (night stock)	22
Mk3 coach High Speed Train (HST) – excluding Class 43 power cars	716
Mk3 coach – excluding Driving Van Trailers (DVT)	178
Mk3 coach (night stock)	61
Mk4 coach – excluding Class 91 power cars and DVTs	271
Total	**1,248**

Table 3.2 – Diesel multiple units

Class	Number of vehicles	Vehicles per unit	Number of units
121	2	1	2
139	2	1	2
142	188	2	94
143	46	2	23
144	30	3	10
144	26	2	13
150	48	3	16
150	226	2	113
153	70	1	70
155	14	2	7
156	228	2	114
158	57	3	19
158	280	2	140
159	90	3	30
165	81	3	27
165	96	2	48
166	63	3	21
168	40	4	10
168	27	3	9
170	267	3	89
170	86	2	43
171	20	2	10
171	24	4	6
172	48	2	24
172	45	3	15
175	22	2	11
175	48	3	16
180	70	5	14
185	153	3	51
220	136	4	34
221	200	5	40
221	16	4	4
222	42	7	6
222	85	5	17
222	16	4	4
Total	**2,892**		**1,152**

Table 3.3 – Electric multiple units

Class	Number of vehicles	Vehicles per unit	Number of units
313	192	3	64
314	48	3	16
315	244	4	61
317	288	4	72
318	63	3	21
319	344	4	86
320	66	3	22
321	468	4	117
322	20	4	5
323	129	3	43
332	25	5	5
332	36	4	9
333	64	4	16
334	120	3	40
350	268	4	67
357	296	4	74
360	84	4	21
360	25	5	5
365	160	4	40
375	30	3	10
375	408	4	102
376	180	5	36
377	708	4	177
377	84	3	28
378	228	4	57
379	120	4	30
380	64	4	16
380	66	3	22
390	44	11	4
390	468	9	52
395	174	6	29
442	120	5	24
444	225	5	45
450	508	4	127
455	548	4	137
456	48	2	24
458	120	4	30
460	64	8	8
465	588	4	147
466	86	2	43
483	12	2	6
507	96	3	32
508	117	3	39
Total	**8,046**		**2,009**

3.1.2 Vehicle characteristics

There are a number of characteristics which distinguish the various classes of rolling stock in operation on the network. These include maximum speed, number of vehicles which operate in formation, seating capacity, vehicle weight, vehicle length, coupling compatability and operational flexibility. **Appendix A** details the passenger rolling stock fleet characteristics.

3.1.3 Maximum speed

The maximum speed at which the various classes of existing rolling stock operate is often lower than their maximum capability because of restrictions imposed by infrastructure. In the case of locomotive hauled stock, the maximum speed is dependent upon the capability of the locomotive power and the brake force of the coaches. Rolling stock currently falls into three categories of speed.

There are a few classes with a maximum speed of 70mph, such as the Class 314 and Class 378, which are usually, although not exclusively, deployed on services where sustained running at higher speeds is precluded either by the stopping pattern or by line speed constraints. Rolling stock with a maximum speed of 75mph typically operates on inner suburban, rural and shorter distance regional services. Approximately 40 per cent of DMUs and 32 per cent of EMUs are in this category.

A significant number of vehicles run at a maximum speed of 90mph or 100mph. Classes in this range are generally deployed on services with longer distances between stops, and over routes where the maximum line speed is higher. This is typically on outer suburban, regional or interurban services. This is the predominant category for multiple units which comprise approximately 42 per cent of DMUs and 62 per cent of EMUs.

The fastest rolling stock currently on the GB domestic network has a maximum operating speed of 125mph, or a design speed of 140mph in the case of Mk 4 and Class 390 vehicles. However, existing infrastructure constraints preclude running at more than 125mph on routes other than High Speed 1 (HS1). The fastest rolling stock is generally deployed on inter city type services, although extensions to these services run beyond the core long distance high speed routes. Most daytime locomotive hauled rolling stock falls into this category. The proportion of DMUs and EMUs (by vehicle) in the highest speed category is approximately 20 per cent and 7 per cent respectively.

3.1.4 Number of vehicles per train

Diesel multiple unit formations are up to nine cars in length, with the majority of DMUs formed as two-car units, reflecting the lower levels of traffic of the routes on which they operate. There are single car units which operate on routes with very low traffic, and three, four, five and seven-car units which operate on longer distance services with higher loadings.

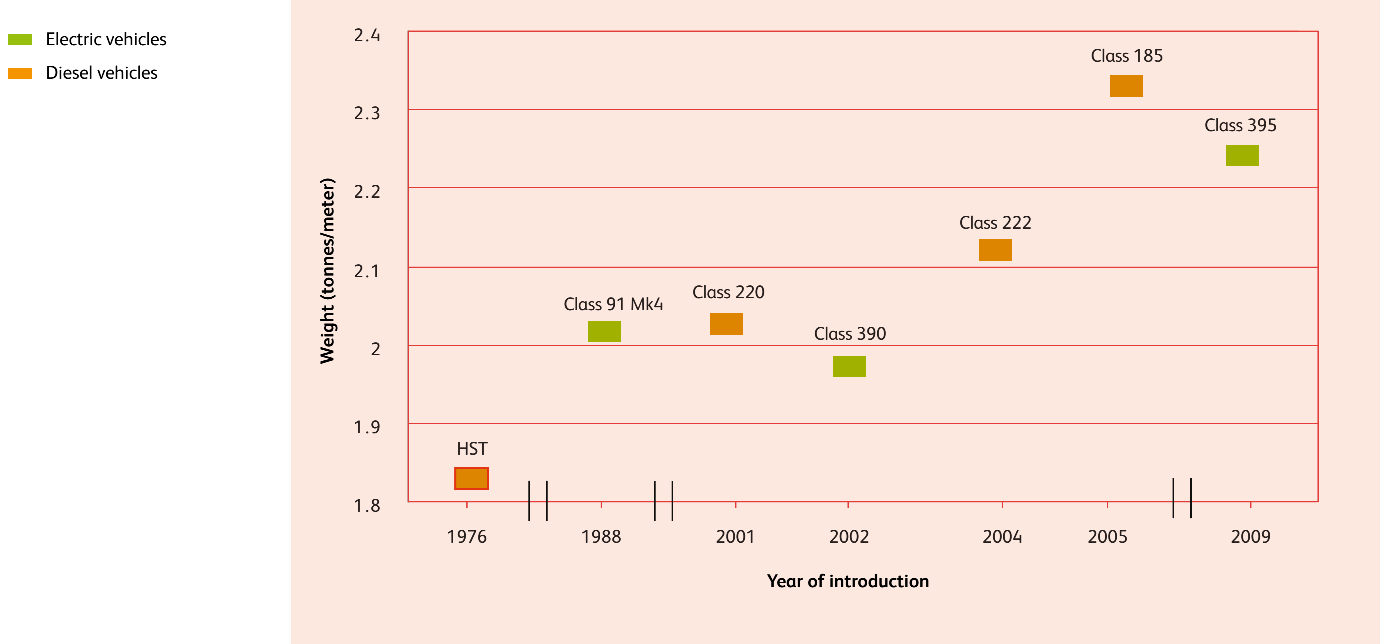
The majority of EMUs are formed as four-car units. Certain classes have longer formations. The current longest are up to nine-car. However, some Class 390s are currently being lengthened to increase formations to 11-car.

The minimum length of an EMU which draws its current from the third rail is two-cars. Even if the demand on such an electrified line were low enough to require no more than a single vehicle, it would not be practical to use a single car unit unless it had an auxiliary power source. A single vehicle would be short enough to be in danger of stopping in a position where none of its shoes were in contact with the conductor rail, and therefore would be unable to move. In the case of EMUs which draw current from the overhead line, the minimum length currently operated is three cars (although there have been two-car units in the past) which reflects the demand typically seen on such routes.

3.1.5 Seating capacity

The seating capacity of an individual unit will depend on the length of the vehicle, the door position, the interior design of the rolling stock, the density of seating and the use of space within the vehicle while providing for other customer requirements, such as luggage space, guard's office, catering provision and toilets. The capacity can vary significantly between individual units or vehicles in a class, because of differences in interior layout, and can often be changed during the lifetime of the vehicle. The interior layout will be influenced by the type of journey for which the train is used. Longer distance services generally have a medium density of seating, with higher densities for shorter distance services. Some rolling stock used on inner suburban services has a higher proportion of space for standing passengers.

Figure 3.1 – Weight comparison of some EMU and DMU vehicles procured in the UK since 1976



3.1.6 Vehicle weight

Vehicle weight is influenced by design, the materials used in its construction and the provision of on-board facilities such as air conditioning and retention tank toilet systems. **Figure 3.1** shows that the tendency has been for the vehicle weight to increase over time, reflecting features such as additional on-board equipment and increased crash worthiness requirements. The greater weight affects the operating cost of the trains, as well as tending to increase wear and tear on tracks. Recent rolling stock specifications have attempted to reverse this trend of increasing vehicle weight. For example, the invitations to tender for the Thameslink rolling stock programme and Intercity Express Programme (IEP) set weight targets.

3.1.7 Vehicle length

With the exception of Pacer DMUs (Classes 142 to 144) whose vehicles are approximately 15 metres in length, rolling stock has a vehicle length of approximately 20 metre or 23 metre. The majority of DMUs are 23 metres long with the exception of the Class 150 vehicles which are 20 metre long. Vehicles of Classes 323, 332, 380, 390, 442 and 444 vehicles are 23 metre long, other EMU vehicles are 20 metre long. Daytime locomotive hauled stock vehicles in regular service are 23 metre long. There has been more recent consideration by the Department for Transport (DfT) toward the introduction of a 26 metre vehicle suitable for long distance high speed services.

3.1.8 Coupling compatibility for multiple unit working

A feature of multiple unit operation is that the length of trains can be increased by coupling individual units together if there is sufficient demand to justify it. Units can be coupled with other units of the same class and in some cases with units of different classes. Even in cases where vehicles can mechanically couple together this does not necessarily mean that they can operate in passenger service as this requires compatibility between the train control systems.

In general the ability to couple with other units of different classes is greater with older classes of unit than in those produced since privatisation of the railway began in 1996. This very desirable requirement has only been partially achieved on more recent fleets; the most notable success would be the Class 170 fleet which can operate with the 15X fleets.

Table 3.4 shows which classes of units can run in multiple with each other and identifies the coupler type used. Within each group any pair of classes can couple together, however on occasions there is some minor loss of train functionality due to different train control systems. It is clear from the table that several types of couplers are in use, most proprietary coupling systems are generally not mechanically capable of coupling with each other. In situations where it is desirable to couple vehicles with different couplers, such as during rescue, adapters are used. Note that there are three classes of DMU and eight classes of EMU that cannot couple to any other class. The incompatibility issues are discussed further in **Chapter 5**.

Table 3.4 – Multiple unit compatibility and coupler types

DMUs		EMUs	
Classes within group	Couplers within group	Classes within group	Couplers within group
14X, 15X, 158, 159	BSI	313, 319	Tightlock
172, 170, 15X	BSI	314, 315, 317, 318, 319, 320, 321, 322, 323, 365	Tightlock
165, 166, 168	BSI	332	Scharfenberg
171	Dellner	333	Scharfenberg
175, 180	Scharfenberg	334	Tightlock
185	Dellner	350, 360	Dellner
220, 221	Dellner	357	Tightlock
222	Dellner	375, 376, 377, 378	Dellner
		395	Scharfenberg
		442	Buckeye
		444, 450	Dellner
		455, 456	Tightlock
		458	Scharfenberg
		460	Scharfenberg
		465, 466	Tightlock
		507, 508	Tightlock

3.1.9 Operational flexibility

The operational flexibility of the fleet is dependant upon a number of factors including vehicle/network compatibility and whether the rolling stock is suitable for the market sector needs. To operate on a route the vehicle and network need to be compatible in key areas such as gauging, power supply and the stepping distance between the train and platform. A number of vehicles currently operating on the network have been designed specifically to work on particular routes, for example the Class 390 which is deployed on the West Coast Main Line where its tilting ability enables it to operate at higher speeds over the route which has many curves.

3.2 Current market sectors and how they are served

The diversity of rolling stock currently operated is best understood by considering the market sector they serve. A useful classification is the definition of market sectors used in the 2007 Rail White Paper, namely:

- long distance high speed
- interurban
- regional
- outer suburban
- inner suburban
- rural.

These can all be defined by the services which are offered to the passenger. Some routes are used by services from several market sectors. The ultimate destinations and the intermediate station stops will often define the service classification.

3.2.1 Long distance high speed

The long distance high speed market sector is distinguishable by the service requirements in that they operate over the longest distances, have a greater distance between stops and travel at high speed. A typical long distance high speed route would be London to Edinburgh or London to Manchester. Vehicles that serve the long distance high speed sector typically need to accommodate high numbers of seated passengers and offer a choice between standard and first class accommodation. Long distance high speed vehicles are the longest vehicles within the current fleet and typically operate at 125mph.

3.2.2 Interurban

The interurban market sector accounts for medium distance routes between regional centres. A typical route of the interurban sector would be Birmingham New Street to Liverpool Lime Street via Crewe or Glasgow Queen Street to Edinburgh Waverley via Falkirk High. The vehicles that serve the interurban sector are required to cover the long distances efficiently whilst offering a high level of passenger comfort. The typical operational speed of vehicles operating interurban services is 100mph.

3.2.3 Regional

The routes served by the regional sector are middle distance – a typical route being the Blackpool North to York or Inverness to Aberdeen service. The regional sector services are often lower frequency at around one train per hour or less. Vehicles that serve the regional routes cover the intermediate distances efficiently and offer a high capacity of passenger seating. The operational speed of vehicles that operate within this sector is typically 100mph.

3.2.4 Outer suburban

A typical outer suburban route is from London Waterloo to Basingstoke. The vehicles that serve this sector need to be able to cover the distances efficiently, meaning that they need to be capable of good acceleration and braking performance with an operational speed of up to 100mph. The high speed profile of the outer suburban vehicles is to ensure that the vehicle keeps up with traffic on main line sections. Doors need to allow large numbers of passengers to board and alight quickly.

3.2.5 Inner suburban

The inner suburban sector operates over routes that serve densely populated areas. The services cater for high passenger numbers travelling over short distances. A typical inner suburban route would be Moorgate to Welwyn Garden City or Glasgow Central to Nielston. Due to the frequent stopping pattern of these services vehicles are required to have high acceleration and braking performance whilst the spacing of stops means that a top speed of 75 mph would normally be adequate. Large numbers of passengers need to board and alight efficiently in order to reduce the dwell time. This influences the door, vestibule and the interior design of the vehicle which typically need to accommodate a large proportion of standing passengers over short journeys.

3.2.6 Rural

The rural sector serves a variety of routes that include short branch lines of a few miles, such as Truro to Falmouth Docks, and longer distances like Morecambe to Leeds. In Scotland the Far North Line operates rural services from Inverness to Wick and Thurso. Although the passenger journeys of some rural services may not be long distance, an appropriate level of comfort is expected. The interior layout may vary and it may not be necessary for the vehicle to have multiple doors. The top speed of the vehicle is typically 75mph as some services are required to use main lines, although on branch lines the speed is likely to be lower. Most rural routes are not electrified so the vehicles which operate on these services are typically self powered.

3.3 Market sector needs of rolling stock

The rolling stock needs of each market sector vary because of the service and passenger requirements. **Table 3.5** outlines the indicative passenger market sector needs. The long distance high speed and interurban market sectors require a vehicle that can seat many passengers and travel at high speeds whereas vehicles which serve the inner suburban routes are required to carry high passenger numbers over relatively short distances and need passengers to board and alight efficiently. The outer suburban and regional routes require a vehicle that can operate efficiently over middle distances and offer the passenger a high level of comfort. The rural routes tend to serve fewer passengers than the other market sectors, although the distances are variable, and as such the vehicles need to offer a level of comfort for a range of journey types.

Table 3.5 – Indicative rolling stock requirements by market sector

Market Requirement	Long distance high speed/ Interurban	Outer suburban/ Regional	Inner suburban	Rural
Design and interior features				
Seating capacity	High	High	Low	Medium
Standing capacity	Low	Medium	High	Medium
Train length/number of carriages	Long	Long/medium	Medium	Medium/short
Premium service required?	Yes	Desirable	Not essential	Not essential
Toilet facilities	Required	Required	Not essential	Desirable
Designated luggage space	Under/between seats, luggage racks, overhead shelving	Under/between seats, luggage racks, overhead shelving	None	Under/between seats, luggage racks, overhead shelving
Air conditioning/ heating	Yes	Yes	Yes	Yes
Safety/security	All emergency and security equipment should be provided as standard. CCTV is desired for all market types. Staff presence may also be required on some services			
Seating type	Comfortable, soft padding, ergonomic shape	Basic, durable, easy to clean	Basic, durable, easy to clean	Basic, durable, easy to clean
Seating layout	Airline seating, table seats/drop-down tables	Airline seating, table seats/drop-down tables	Flexible (seats, perch and tip-up seats)	Flexible
On-board information	Passenger information displays and automatic announcements			
At-seat accessories	Wi-fi, at seat lighting, power outlets, magazine racks, adjustable blinds	Wi-fi, at seat lighting, power outlets, magazine racks, adjustable blinds	None	None
Grab rails/poles/ handles	Yes	Yes	Increased number of grab rails/poles/ handles	Yes
Accessibility features				
Wheelchair and buggy space(s)	Yes	Yes	Yes	Yes
Nappy-changing facilities	Yes		No	Desirable
Priority seating	Yes	Yes	Yes	Yes
Service characteristics				
Service frequency	Medium	High	High	Medium/low
Frequency of stops	Low	Medium	High	Medium
Passenger access/ egress speed	Minimise dwell time		Minimise dwell time, increase space surrounding doors	Minimise dwell time
Traction power	AC or self powered	AC, DC or self powered	AC or DC or self powered	AC, DC or self powered
Operational speed range	125 – 140mph	100 – 125mph	70 – 90mph	70 – 90mph

3.3.1 Determining rolling stock allocation

Commercial agreements with vehicle owners need to be reached before rolling stock is used. Franchising, market sector requirements and cost play a part in the allocation of rolling stock to services for each market sector. Factors such as physical characteristics and the interface between the rolling stock and the infrastructure come into play. These factors will be discussed further in **Chapter 6**.

Franchise renewal provides an opportunity for the introduction of new or cascaded rolling stock (rolling stock transfer between routes) as well as the reintroduction into service of existing rolling stock previously held in store, if it represents value for money. In the past franchise agreements have specified the services and routes of a franchise including an overview of the rolling stock available for the specific franchise.

3.3.2 Vehicle cascade

The introduction of new vehicles may trigger the displacement of incumbent rolling stock for the reuse on other services within the operating area, or to another franchise elsewhere on the network. Initial cascades may also trigger a second displacement of rolling stock to other franchises. So far, most cascades have provided only one interation of rolling stock displacement. **Figure 3.2** gives a graphical representation of the cascade process.

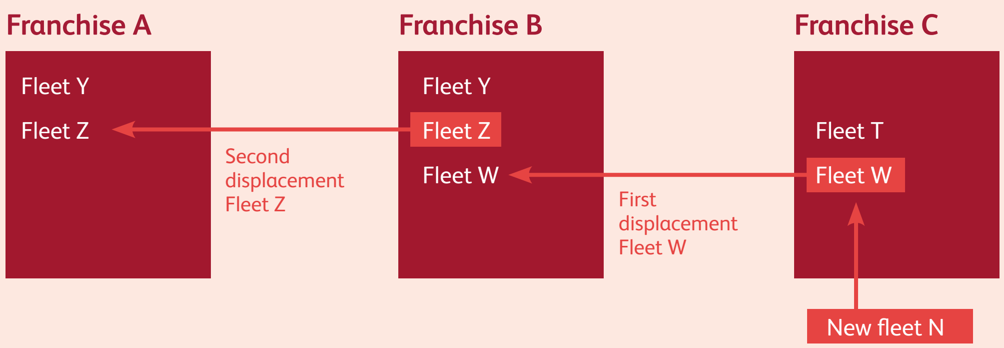
New fleet Introduction: When new vehicles are introduced they can displace existing fleet and trigger the movement of the existing fleet either wholly or partly. For example, new Class 378 trains on London Overground made Class 313s surplus to requirement. These vehicles were then re-deployed to Southern for its Coastway service and to First Capital Connect to provide extra capacity on urban metro services into Moorgate.

Franchise obligation: There may be a franchise obligation to renew or replace the rolling stock. This could be to provide 'extra capacity' for growth on certain routes, either providing additional vehicles or 'route extension' where the same fleet is required to be extended in service to additional routes on the network.

Changes in demand: Timetabling requirements sometimes lead to a change in demand for rolling stock and as a result rolling stock is transferred from one franchise to another to satisfy the changes in demand.

Short-term loan and return: A short-term need is sometimes addressed by the hire of rolling stock on the understanding that the rolling stock will be returned.

Figure 3.2 – Fleet cascade



Source: Competition Commission report April 2009

This is often caused by other cascades taking place. For example Class 321s were used in 2007 to supplement the c2c fleet while Electrostars were being modified and tested for regenerative braking capability, and London Midland has loaned Class 153 vehicles to Northern Rail to strengthen their fleet.

Swaps: In some instances one TOC has exchanged rolling stock with another.

Swaps typically occur because alternate rolling stock may meet the operational requirements or a particular route better. These transactions may involve new lease agreements between the relevant TOCs and ROSCOs.

Figure 3.3 summarises the types of cascades that have taken place between 1998 and 2008 as detailed in the Competition Commission report analysis. It shows the reasons for movements of rolling stock by number of vehicles and percentage of total. This clearly shows that the vast majority of cascades (70 per cent) are 'first displacements' (ie one stage cascades). The next closest is 'subsequent displacement' at 12 per cent.

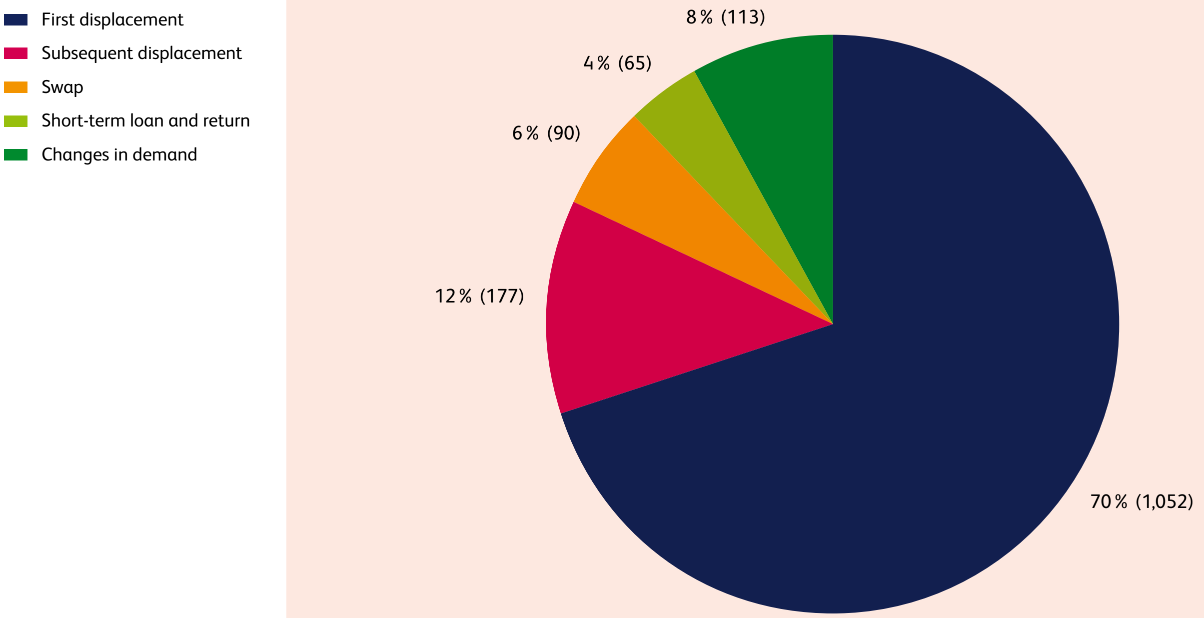
3.3.3 Commercial life of rolling stock

The main factors which influence the commercial life of rolling stock are:

- external events
- physical condition
- market considerations
- changes to attributes of infrastructure.

Under each of these elements there are a number of trigger events that would require some consideration. These events, possible responses to them and the extent to which they might influence the commercial life of rolling stock are discussed in turn.

Figure 3.3 – Fleet cascade types



Source: Competition Commission report April 2009

External events

External events include changes in the market, the introduction of new legislation and changes to whole life cost which may make it increasingly attractive to run electric traction rather than diesel services on electrified lines. **Table 3.6** shows the principal factors and their potential effect on the commercial life of rolling stock.

Table 3.6 – External Events which effect the commercial life of vehicles

Factor	Trigger	Possible responses	Considerations which affect the degree to which factor influences vehicle life
Market size or composition	Downturn in demand in a market segment or line closure	Withdraw, redeploy or store vehicles	Would address in the longer term by adjusting new build, could lead to the early withdrawal of the oldest vehicles
	Growth demand in market segment faster than can be accommodated by building new	Life extend vehicles/ redeploy	Would address in the longer term by adjusting new build, could lead to life extension of the oldest vehicles
Legislation	A characteristic of the vehicle ceases to be compliant with legislation	Modify (where possible), seek derogation or withdraw	Date of trigger is fixed once legislation is enacted (unless derogation obtained)
Whole life cost	Significant increase in cost of diesel or biofuels	Refit with fuel efficient engines (where possible) or withdraw	Size of differential in fuel cost, and extent of electrification, will influence vehicle life foregone

Physical condition of vehicles

The physical condition of a vehicle is an important determinant of its commercial life, as it will influence the cost with which the vehicle can be kept in a suitable state for continued service. **Table 3.7** shows the principal factors and their potential effect on the commercial life of rolling stock.

Table 3.7 – The impact that vehicle condition has on rolling stock commercial life

Factor	Trigger	Possible responses	Considerations which affect the degree to which factor influences vehicle life
Bodyshell condition	Bodyshell becomes weak /corroded to extent that integrity is lost	Withdraw vehicle	Fundamental determinant of commercial life
Bogie/wheel set condition	Bogies or wheel sets worn /corroded beyond repair	Replace bogies/wheel sets or withdraw vehicle	Bogies can be reused on compatible vehicles, so likely to affect vehicle life only if remaining life is short
Engine/traction motor condition (for motored vehicles)	Maintenance cost increases and /or reliability/availability falls to unacceptable level	Replace or heavy overhaul or withdraw vehicle	Engines can be replaced, in some cases the traction motors reused on compatible vehicles, but at a significant cost
Technical obsolescence	Computer systems controlling operation of vehicle or signalling/train interface can no longer be supported	Replace systems or withdraw vehicle	Depends on extent to which modular design allows straightforward replacement/reuse of the systems
Traction package obsolescence	Traction package becomes difficult/ impossible to maintain	Replace package or withdraw vehicle	Traction package can be replaced, so likely to affect vehicle life only if remaining life is short

Market considerations

Market considerations will also influence the commercial life. The extent to which the condition and performance of vehicle is suitable for the markets it serves may diminish with the age of the vehicle, particularly when set against rising passenger expectations. Ultimately, the commercial life of a vehicle will be determined by how well it serves its market, ongoing lease and operational costs.

Table 3.8 shows the principal factors which may impact upon demand and consequently affect the commercial life of rolling stock

Table 3.8 – Impact of market considerations on the commercial life of rolling stock

Factor	Trigger	Possible responses	Considerations which affect the degree to which factor influences vehicle life
Passenger experience	Overall passenger experience deemed no longer acceptable	Withdraw vehicle	Poorest quality vehicles generally on low revenue routes, so it is difficult to make the business case for replacement on this factor alone
Journey time	Market growth/market review requiring faster rolling stock	Cascade or withdraw vehicle	Provided mechanisms exist for sensible cascade, this is likely to only influence the vehicle life among the oldest in the fleet
Vehicle interior	Vehicle interior becomes 'tired' – less attractive to market	Cascade vehicle or interior refit/refresh/refurbish/reupholster Heavy interior clean	Range of responses is sufficiently wide that the response is likely to be driven by remaining life of vehicle (as determined by other factors), rather than affecting vehicle life

Changes to attributes of the infrastructure

Changes to attributes of the infrastructure will potentially affect the suitability of certain classes of rolling stock for the infrastructure, which in turn may also influence the commercial life of the vehicles.

Table 3.9 shows the principal factors and their potential effect on the commercial life of rolling stock.

Table 3.9 – Changes to attributes of the infrastructure

Factor	Trigger	Possible responses	Considerations which affect the degree to which factor influences vehicle life
Speed	Line speed (or differential line speed) increase allowing faster rolling stock	Cascade or withdraw vehicle	Significant infrastructure upgrades should be planned in conjunction with rolling stock replacement plans
Performance characteristics	Capacity constraint requires trains of similar characteristics on congested route	Modify, cascade or withdraw vehicle	The primary effect of these factors is likely to be on vehicle deployment (provided mechanisms exist for sensible cascade) but could affect vehicle life at the margin
Vehicle or axle weight	Change in use/asset condition requires light weight (or low axle weight) vehicles	Cascade or withdraw vehicle	
In Cab signalling (ERTMS)	Provision of ERTMS on route	Modify, cascade or withdraw vehicle	Significant infrastructure upgrades should be planned in conjunction with rolling stock replacement plans

3.4 Routes which serve each market sector

The maps in **Figures 3.4, 3.5, 3.6, 3.7, 3.8** and **3.9** show the routes which constitute each market sector.

The maps illustrate that whilst some routes are relatively simple and serve only one market sector, the majority are complex and serve multiple market sectors and as such a variety of rolling stock types operates over them.

Figure 3.4 – Long distance high speed services (indicative)

Figure 3.5 – Interurban services (indicative)

Figure 3.6 – Inner suburban services (indicative)

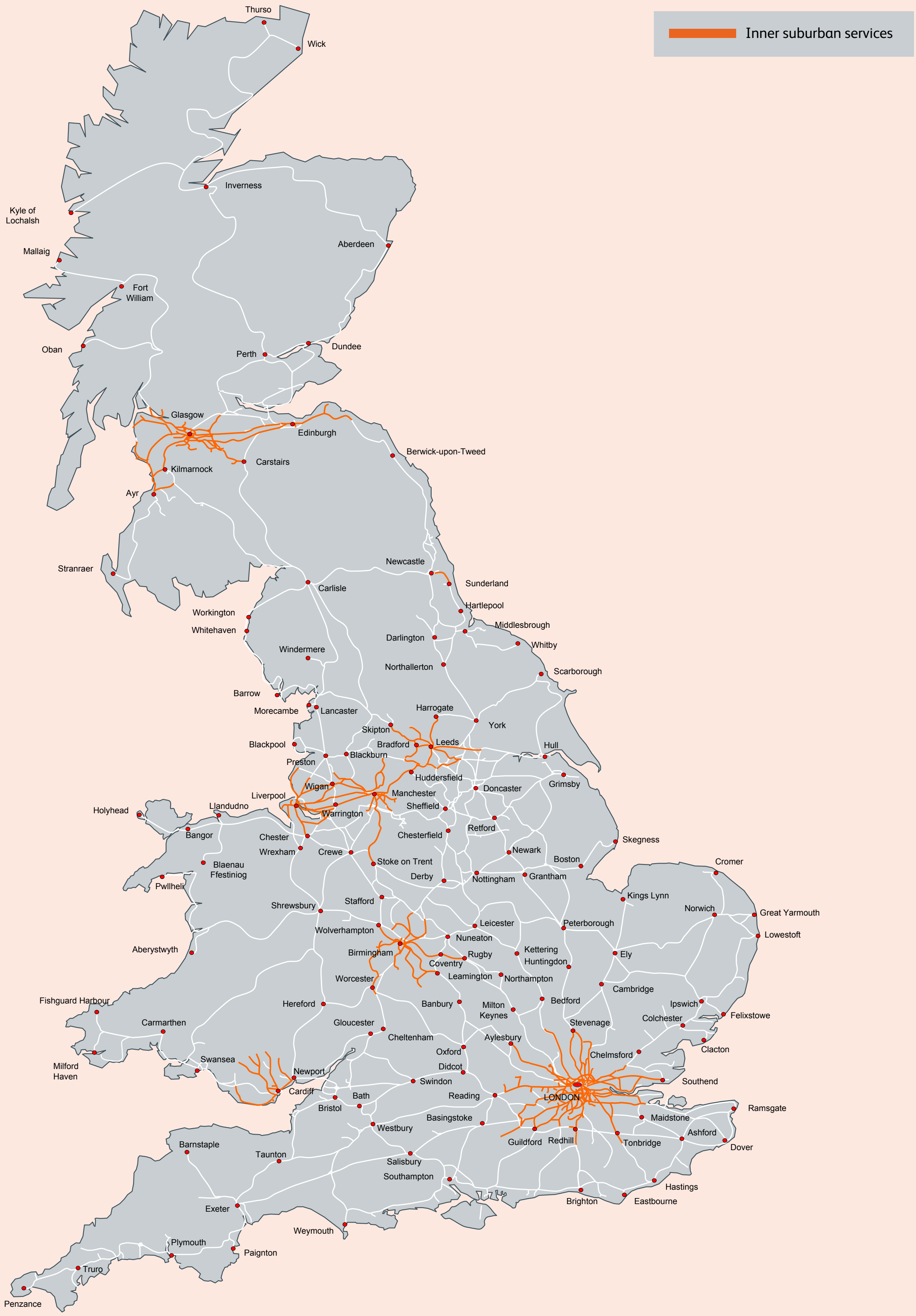


Figure 3.7 – Outer suburban services (indicative)

Figure 3.8 – Regional services (indicative)

Figure 3.9 – Rural services (indicative)

3.5 Current infrastructure committed plans

During Network Rail's Control Period 4 (2009 – 2014) a number of infrastructure enhancement schemes will deliver capacity improvements. These include rolling stock integration and route enhancement work.

3.5.1 Thameslink Programme

The Thameslink Programme includes substantial remodelling of the London Bridge corridor as well as other enhancements to the outer areas, such as the provision of platform extensions, power supply upgrades, route clearance works and additional stabling facilities. The Thameslink programme has phased delivery over three key outputs. One was completed in March 2009, the other two are due for completion in December 2011 and December 2018 respectively. New rolling stock is expected to be introduced on Thameslink services from 2015, as indicated in the London and South East RUS.

3.5.2 Intercity Express Programme

On 1st March 2011, the Government announced that it has decided to resume the Intercity Express Programme procurement. The first of the new trains are expected in service on Great Western Main Line (GWML) in 2016 and the East Coast Main Line by 2018.

The Intercity Express Programme has been led by the Department for Transport, with assistance from across the rail industry, since November 2005.

The Programme seeks to replace the 'Intercity 125' High Speed Train diesel fleet procured by British Rail during the 1970s and 1980s with a new, higher capacity, more environmentally friendly train.

The programme will see the building of a substantial number of electric and bi-mode (diesel and electric) long distance trains which will run to GWML stations including Oxford, Swindon, Reading, Cardiff Central, Swansea, Bath and Bristol Temple Meads and to East Coast Main Line stations such as Peterborough, York, Doncaster, Newcastle, Edinburgh Waverley, Aberdeen and Inverness.

3.5.3 Electrification

There is an electrification programme in the North West of England and on the GWML. On 1st March 2011 the Government announced that the Great Western element of the programme would be extended westwards to Bristol Temple Meads and Cardiff Central. **Figure 3.10** shows the current electrified routes, committed schemes and the core schemes in the Network RUS: Electrification strategy.

3.5.4 Crossrail

The Crossrail project aims to deliver infrastructure enhancements to enable operation of 24 trains per hour from central London to destinations such as Heathrow Airport, West Drayton and Maidenhead in the west and Abbey Wood and Shenfield in the east initially. The scope of works include:

- construction of subsurface railway infrastructure under central London with a tunnelled extension to Docklands via Canary Wharf
- platform extensions for stations from Maidenhead to Abbey Wood and Shenfield to cater for 200 metre long electric trains
- enhancements to the existing infrastructure
- the development of appropriate depot maintenance facilities.

There are plans to order a fleet of new trains of 200 metres in length.

3.5.5 Train lengthening programme

A train lengthening programme will allow the operation of longer trains on key routes within the south east of England. The programme of enhancements will provide the following capability:

- 10-car capability on certain suburban services on the Wessex route into London Waterloo
- 10-car capability on certain suburban services on the Sussex route into London Victoria
- 10-car capability on certain suburban services on the Sussex route into London Bridge
- 12-car operation on the Sussex route from East Grinstead into London Victoria and London Bridge
- 12-car capability on certain Kent route suburban services into London Charing Cross and Cannon Street
- 12-car capability on the Anglia route (Tilbury Loop and Ockendon Branch) into London Fenchurch Street
- 12-car capability on the certain West Anglia services on the Anglia route into London Liverpool Street.

The capability changes will be delivered to different timescales across Control Period 4. Longer services will be possible on or before the December 2013 timetable change date.

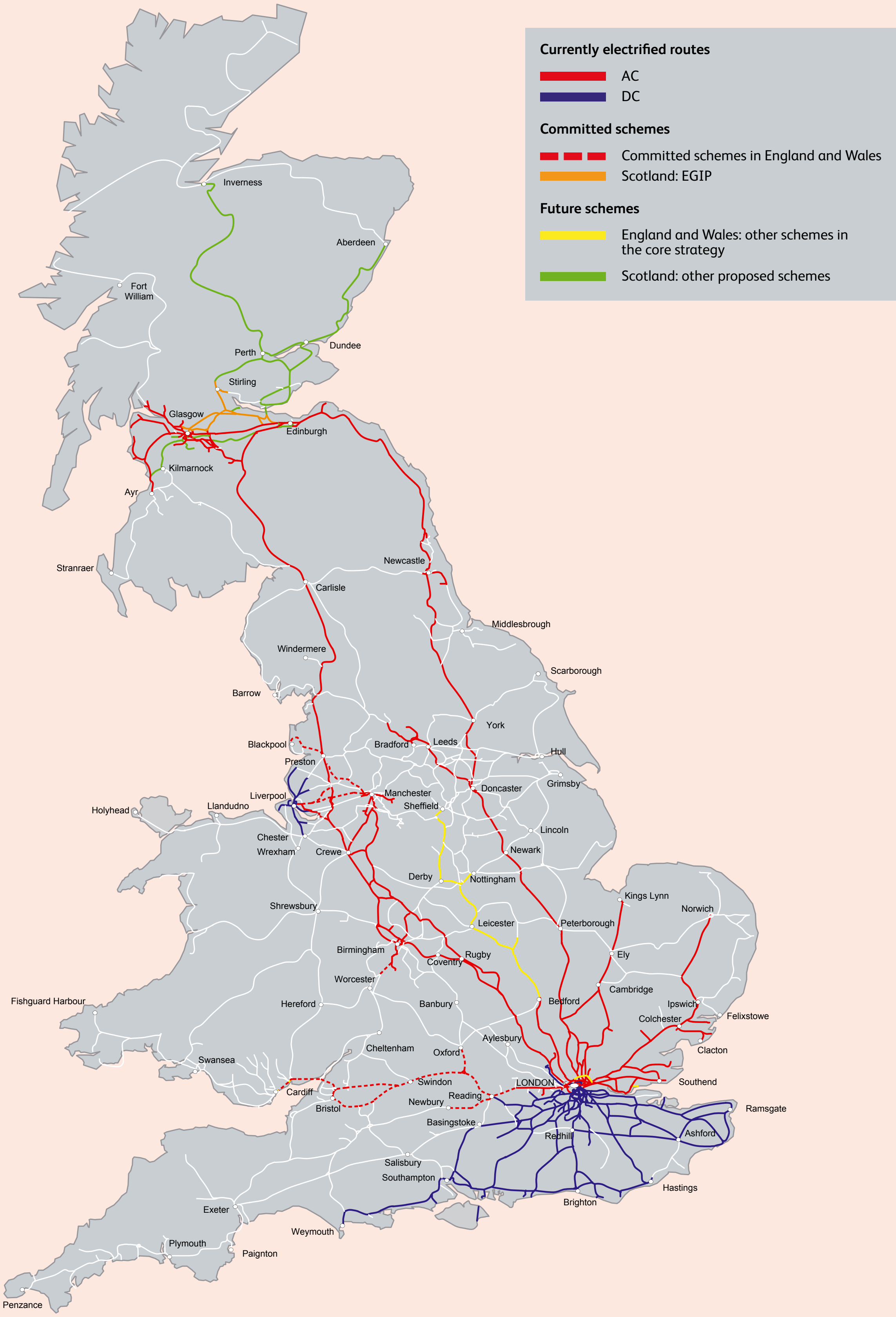
3.5.6 Edinburgh to Glasgow Improvement Programme

The Edinburgh – Glasgow Improvement Programme consists of a series of improvements, including electrification, between Scotland's two largest cities and the wider central Scotland corridor. Work is scheduled to be completed by 2016.

The improvements are designed to support the communities, environment and economy of the region. The project will provide an immediate boost to the local economy during construction, but more importantly will stimulate long-term growth and unlock investment opportunities in the area.

The project is planned to deliver a faster and more frequent service between Edinburgh Waverley and Glasgow Queen Street along with new or increased service opportunities. Investment is planned at Haymarket station to improve the current facilities and concourse, as well as providing an interchange with the forthcoming Edinburgh tram.

Figure 3.10 – England and Wales core Electrification Strategy and Scotland schemes



3.6 Current rolling stock costs

Rolling stock costs can be broken down into initial costs and operational costs. The costs of rolling stock vary according to the class of vehicle; however, the costs associated with an electric vehicle are distinctly lower than that of an equivalent diesel vehicle.

3.6.1 Procurement & leasing costs

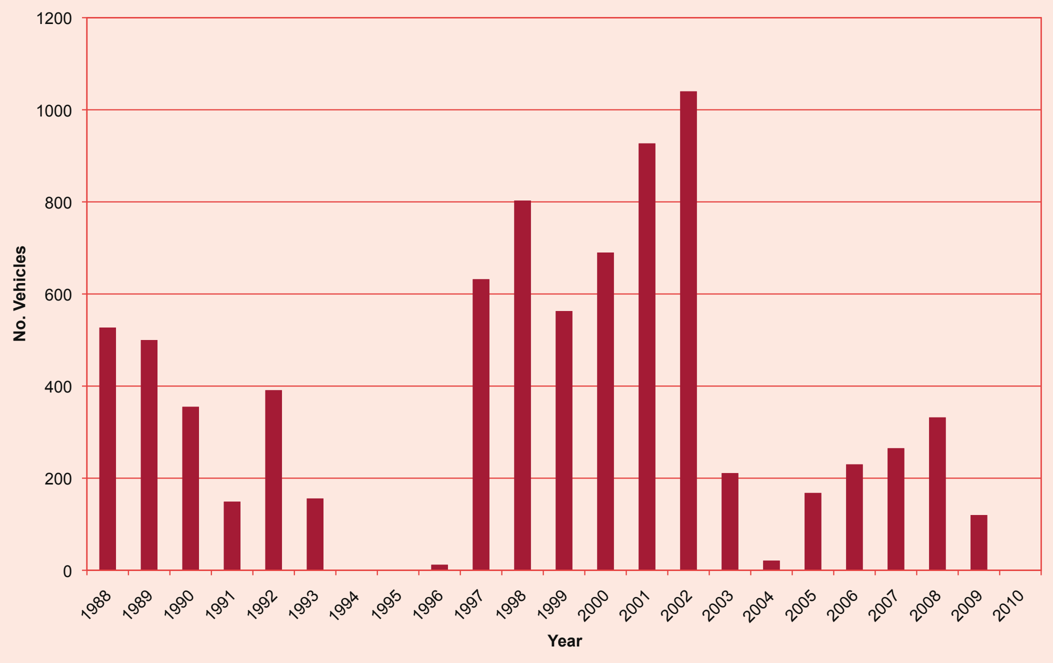
Although the procurement of new rolling stock is an infrequent event, the costs involved are considerable. **Figure 3.11** shows the past procurement of DMU and EMU passenger vehicles in Great Britain. The graph highlights that there has not been a consistent pattern of procurement. There were very few orders placed between 1994 and 1997 around the time which the industry was privatised.

The principal drivers of lack of continuity have actually been:

- initial privatisation of the railway
- the Mk 1 withdrawal deadline imposed by Government
- government decisions to bundle IEP and Thameslink procurements
- short franchises periods, forcing new train procurement and refurbishment to be done in a great rush early in the franchise.

The procurement costs of rolling stock is dependant on a number of factors, particularly, the vehicle class and traction type. External factors such as exchange and funding rates also have an influence.

Figure 3.11 – Passenger rolling stock orders between 1988 and 2010



Source: Rail Industry Association (2010)

The cost of rolling stock has varied considerably in recent years. **Figure 3.12** shows that between 1998 and 2007 there were 4,648 vehicles ordered with an average cost per vehicle was approximately £1.1m (Source: Competition Commission). However, this was some years ago, and inflation and exchange rate changes will have had an effect. Sir Roy McNulty's value for money study suggested a range per vehicle of £1m – 1.4m, while the vehicle leasing companies have suggested that £1.4 – 1.6m for standard vehicles but approaching £2.0m for high specification vehicles is currently more realistic.

Since privatisation, the ROSCOs and others have financed new rolling stock. The DfT and operators have been involved in the procurement and specification of vehicles to meet the aspirations of the High Level Output Specification (HLOS).

The total leasing and maintenance costs of rolling stock can generally be considered as approximately 15 per cent of the total industry costs at around £1.8bn. **Table 3.10** estimates the typical operational costs of a diesel and electric vehicle. Costs will vary by the class of unit, but, on average the costs of operating an electric is considerably less than that of a diesel vehicle.

3.6.2 Maintenance costs

Rolling stock maintenance costs are dependent upon a number of factors such as the class, traction type and age of vehicle. Electric vehicles have a lower maintenance cost than diesel vehicles. The frequency of maintenance is lower for electric vehicles, and this in turn gives higher vehicle availability ie the ratio of the number of vehicles available to operate the service to the total number of vehicles in the fleet. This is discussed further in the established Network RUS: Electrification strategy.

Figure 3.12 – Average price per vehicle (nominal) by year of order since privatisation (1998 – 2006)

Source: Competition Commission report April 2009

Table 3.10 – Typical operational costs of diesel and electric passenger vehicles (Source: ATOC)

	Typical value for diesel vehicle	Typical value for electric vehicle
Maintenance cost per vehicle mile	60 pence	40 pence
Capital lease cost per vehicle per annum	£110,000	£90,000

4. Drivers of change

This chapter outlines those factors which could potentially drive a change in the industry's approach to a strategy for new rolling stock on the network, given the objectives of the industry's stakeholders. The predominant drivers are related to the objectives of; the need to provide a railway that is value for money; delivering the railway more efficiently; maintaining and improving the industry's environmental credentials; and taking advantage of technological developments.

4.1 The need to provide value for money and minimise whole industry whole life costs

The cost of running the British rail network is currently estimated to be £10.9 billion per annum, of which approximately £4.8 billion is funded through subsidy. The rail industry, Department for Transport (DfT), Transport Scotland and the Welsh Government are united in an objective of obtaining value for money and minimising these costs. Rolling stock procurement and operation costs are substantial. Between 1998 and 2007 approximately £4.6 billion was spent on the procurement of new vehicles[1]. As such a large cost item, reductions in the costs of rolling stock have the potential to make a substantial impact on the overall costs of the railway.

A number of manufacturers of rolling stock vehicles have indicated that the cost of rolling stock could be substantially reduced if larger orders of a consistent vehicle type were procured over a period of time. Similarly, a number of manufacturers have stated that the rolling stock supplied to Britain in the past has often been of a bespoke design which contributes towards a higher unit price than would be the case if there were repeat orders of the same design. There would inevitably be certain design considerations which would be specific to Britain, such as the vehicle size which differs from that produced for gauges in Europe. Nonetheless, manufacturers believe that efficiencies could be obtained from using design platforms which comprise standardised equipment.

The operational railway is a complex system where many interfaces exist between rolling stock and the infrastructure over which it is required to operate. Historically the national rail network was developed in various stages and as a result there are variations across the network in electrification, gauge and platform lengths. The variation of the network has, in part, contributed to the introduction of the many different rolling stock types in operation today. Each type has a different amount of network coverage. Given the variations across the network, it is important that rolling stock and the infrastructure are planned together to ensure vehicle and network compatibility in meeting passengers' needs. Rolling stock which is planned to serve a whole market sector rather than a route could enable both whole life cost savings and enhanced operational flexibility of a fleet.

Operating vehicles which cause less wear and tear to the infrastructure will not only incur less operating costs (lower track access charges) but will also mean that there is a reduced requirement to undertake maintenance or renewal of the track asset, increasing the availability and reliability of the network. This also increases the capacity of the network by reducing the amount of time that the network is unavailable due to maintenance activities.

4.2 Increased electrification of the railway

The established Network RUS: Electrification Strategy was published in October 2009. The DfT has announced that it is prepared to fund substantial elements of the core strategy which included electrification of the Great Western Main Line from London Paddington to Cardiff Central, Bristol Temple Meads, Newbury and Oxford and electrification of key routes in northwest England. Transport Scotland is progressing with additional electrification between Edinburgh Waverly and Glasgow Queen Street and has included more extensive electrification plans in their Strategic Transport Project Review.

The extent of further network electrification will clearly have a bearing on the number of electric vehicles and self powered vehicles within a fleet. If the electrified network is increased further, then the proportion of the fleet which needs to be self powered will be reduced, enabling the industry to exploit the cost advantages that electric vehicles offer over diesel powered vehicles. In the next few years many of the diesel powered vehicles on the network will approach life expiry, triggering decisions about their replacement. As the cost of diesel fuel rises, the advantages of electrification become

1 Competition Commission, Rolling Stock Leasing Investigation, July 2009

more apparent. Electrification of the network brings benefit to freight operating companies in that they also can operate electric locomotives over a wider range of trunk routes.

Whilst electrification is an efficient solution for many lines, the Network RUS Electrification strategy recognised that many routes are unlikely to have a business case which would be sufficiently strong to justify investment in conventional electrification infrastructure. On these routes self powered modes, or cheaper alternatives to conventional electrification may warrant further investigation.

4.3 An increased need for operational flexibility

As funders and operators strive to bring down the costs of the railway, it is becoming increasingly important to identify efficiencies that might arise from optimising operational flexibility. Rolling stock fleets which are cleared for operating widely on the network allow much more flexibility than those with a narrow coverage. Such increased operational flexibility could be efficient for Train Operating Companies (TOCs), the Rolling Stock Companies (ROSCOs) and other investors that supply the vehicles and ultimately passengers benefit from more operationally flexible vehicles where the increased vehicle coverage of routes allows operators to offer new services. The TOCs would benefit by having a vehicle fleet that is less diverse and more interoperable, logistically easier to manage allowing them to respond to demand more easily.

Lessors would benefit by having vehicles which are more easily cascadable which reduces their commercial risk, thereby potentially maintaining their residual value. Cascading vehicles which are operationally flexible becomes inherently easier as their compatibility with the network and with other vehicles becomes less of a constraining factor.

4.4 Opportunities to exploit technical improvements

Modern rolling stock can offer improved operational performance which can help address customer aspirations. Recent advances in rolling stock design have seen improvements in vehicle acceleration and braking capability, improved operating performance, and, potentially, opportunities to improve the utilisation of network capacity.

Technological advances have also improved reliability as better quality of components and sub-systems enable vehicles to operate with fewer failures. The use of standard components and design platforms by manufacturers has meant that some design features and sub-systems are utilised in greater numbers, eradicating anomalies. The design of the interior fitting of rolling stock can also exploit technological advances to meet passenger requirements. For example, carriages are increasingly fitted with passenger power supply sockets, wifi, modern toilets, air-conditioning, customer information screens and disabled passenger access.

New technologies will bring significant changes to the way in which future rolling stock operates. Technologies to reduce noise, emissions and carbon are all in development. Designers are considering battery powered units, fuel cell engines and innovative ways to electrify routes where infrastructure problems have previously precluded this on the grounds of cost.

Future rolling stock and infrastructure could be based upon more open architecture with standard interfaces and a modular approach to design with 'plug and play' equipment to reduce train and infrastructure costs.

4.5 The need to replace ageing rolling stock

Over the next 10 to 15 years, a significant proportion of the passenger rolling stock currently operating on the network will be at least 30 to 35 years old, the age traditionally regarded within the industry at which a vehicle approaches the end of its commercial life and will require replacement or life extension.

A number of factors determine when a vehicle needs to be replaced and, conversely, whether its commercial life can be extended. These include:

- technical – there will be a need to understanding whether a vehicle life can be extended technically. If it can then there will be a need to evaluate whether it makes sense commercially
- economic – the operational and maintenance costs associated with a vehicle may make it less competitive than that of new, more modern rolling stock. The current condition of the vehicle may be such that it requires a high amount of investment in order to life extend it for a longer period of time. Any decision to extend the commercial life of a vehicle involves a consideration of the relative value of deferring the replacement expenditure against the additional costs associated with extending its life
- operational – the ability of the rolling stock to serve a particular market sector in terms of the operational coverage needs to be considered
- maintenance – the maintenance costs associated with older vehicles vary but can be higher or lower than some new vehicles. The availability of spares and the obsolescence of parts needs to be considered
- performance – all vehicles need to contribute to service performance targets; if a vehicle is to be life extended, technology upgrades may be necessary. However this may require the use of bespoke sub-systems which can be high in cost
- passenger aspirations – the needs and aspirations of passengers in any market sector change over time. The aspirations may be met by replacement vehicles or by refitting existing vehicles.

Vehicle life extension programmes require part of the fleet to be unavailable at any given time. Replacement vehicles may need to be used or services compromised for a period.

4.6 Growth in passenger demand

The industry is currently preparing long term plans for publication in an Initial Industry Plan (IIP) in September 2011. It is forecasting that the growth in demand resulting from expected economic growth and population changes will be in the order of 80 per cent by 2034. This excludes additional growth which would be stimulated by further improvements to the railway, which could be significant.

The replacement of existing rolling stock on a like for like basis would not accommodate this growth. The expected growth, in passenger kilometre by sector, is summarised in **Table 4.1**. Although some spare capacity exists on the network at present (and assuming that average passenger journey lengths remain constant), the industry will require additional vehicles to accommodate this growth.

The procurement of new rolling stock needs to be considered against the future passenger growth estimates.

Table 4.1 – Summary of long term passenger growth

Market	Passenger km growth to 2034	Average rate per year
London commuter	40 %	1.3 %
Long distance	68 %	2.0 %
Regional urban commuter	104 %	2.8 %
London other	90 %	2.5 %
Regional urban other	116 %	3.0 %
Rural	90 %	2.5 %

Source: Planning Ahead 2010 (RFOA, ATOC & Network Rail)

4.7 Environmental concerns

The environmental challenges that the UK faces are considerable, and the railway must continually consider ways to improve its performance. The Government has set a general target of reducing carbon dioxide emissions by 80 per cent by 2050. Whilst rail currently produces less carbon per passenger kilometre than its main competitor, the private motor vehicle, it will nonetheless need to ensure that it innovates to maintain that position. Other transport modes will undoubtedly face similar challenges in meeting improvement targets. However, as the asset life of, say, a motor vehicle is shorter than that of rolling stock, so the implementation of new technology may be faster in these other modes.

The procurement of new and more modern rolling stock can offer benefits of reduced emissions by addressing technical and operational changes:

- technical changes: new rolling stock can weigh less, have improved aerodynamics, reduce traction system losses, use regenerative braking, improve space utilisation and improve passenger comfort
- operational changes: modern rolling stock designs can offer increased load factors and efficient driving strategies.

The extension of the electrified network will bring an opportunity to replace diesel vehicles with more environmentally friendly electric vehicles. Life extension of existing vehicles could well include more modern traction packages.

In overall terms, rail's carbon emissions are relatively low, with rail responsible for less than one per cent of total Great Britain's carbon emissions. Increasing numbers of passenger and freight services, combined with the introduction of heavier and higher performance trains, has resulted in modest increases in rail carbon emissions over the past decade. However, rail's carbon efficiency – measured in terms of the amount of carbon emitted per passenger or tonne transported – remains good. In addition, the net impact of increasing rail activity on carbon emissions must take account of modal shift, where passengers and goods travel by rail instead of road or air. If a strong modal shift can be demonstrated, then additional rail activity could lead to a net reduction in carbon emissions.

However, it is clear to the Government that rail must improve its carbon efficiency in order to maintain its environmental advantage over other modes and to reduce its operating costs. The rail industry has also recognised the importance of improving its environmental performance to its longer term success.

4.8 Legislation

A number of pieces of forthcoming legislation will influence the rolling stock choices that are made by the industry. New vehicles which are brought onto the network must be compliant with current legislation.

4.8.1 Accessibility

Rail Vehicle Accessibility Regulations (RVAR) have applied to all new rail vehicles entering service in Great Britain since 31 December 1998. They standardised accessibility requirements to meet the needs of disabled passengers including, for example, provision for wheelchair users, the size and location of handrails, handholds and control devices as well as the provision of passenger information systems and other equipment. However, on 1 July 2008, a new European standard for the accessibility of passenger rail vehicles, the Technical Specification for Interoperability for Persons with Reduced Mobility (PRM TSI) came into force. The PRM TSI applies to all trains used on the interoperable rail system, which comprises the major lines of the mainline rail system in Britain. It also covers the accessibility of railway stations and related infrastructure. 46 per cent of the national heavy rail fleet has been built to modern access standards, as at March 2011.

As well as new rail vehicles, the PRM TSI also applies to older rail vehicles (those introduced prior to 1999) when they undergo refurbishment. Specific United Kingdom (UK) law requires that all rail vehicles, both heavy and light rail, must be accessible by no later than 1 January 2020.

4.8.2 Interoperability

Interoperability is a European initiative aimed at improving the competitive position of the rail sector with other transport modes, and in particular with road transport.

The Government expects interoperability to benefit the UK by:

- delivering economies of scale in the cost of components and equipment through the single market
- providing a consistent and simple pan-European approvals system for putting railway assets into service
- reducing, to the extent that it will be possible for the UK, the barriers to the through operation of trains throughout Europe.

Interoperability will grow by the progressive adoption of technical standards as the rail system is renewed or upgraded, and new assets are built. It can be effectively achieved or built into enhancements only when a railway asset is at the design and build stages of its lifecycle. This is why the regulations are directed at new build and at major work during the life of the asset which presents opportunities to increase standardisation.

The rail industry needs to engage with the Railways (Interoperability) Regulations 2006 whenever it is embarking on a project for new build, or upgrade or renewal of existing assets. The regulations establish a framework and set standards within which that project must be carried out. They do not require the industry to undertake work purely for the purpose of delivering interoperability.

The DfT is working with the railway industry to ensure that the UK Interoperability Implementation Plan will add commercial and technical value to the UK.

4.8.3 Non-Road Mobile Machinery Directive

The Non-Road Mobile Machinery (NRMM) European Directive regulates exhaust emissions from non-road machinery engines, including those powering diesel rolling stock. NRMM sets engine exhaust emissions limits for new engines for non-road applications, including rail. This will require increasingly stringent standards for new engines, including new replacement engines which may be a driver of change for replacement of self-powered rolling stock.

4.8.4 Management of noise

EU Directive 2002/49/EC on the management of environmental noise requires member states to produce noise maps and action plans for major transport infrastructures including railways. The directive requires railway operators to consider noise impacts when drawing up action plans regarding infrastructure. By 2013 Member States must ensure that all authorities have drawn up action plans for all major railways in their territories.

In order to adhere to the directive, the Government published the Noise Policy Statement for England (March 2010). It seeks to fulfil the directive's requirements.

It is expected that railway lines carrying more than 80 trains each way per day will have to adhere to the directive. As yet it is unclear as to how this will directly impact upon existing rolling stock and when planning for new rolling stock.

5. Gaps

5.1 Introduction

This chapter outlines the key gaps which can be identified between today's railway and a future railway and which, if bridged, could exploit benefits derived from the drivers of change identified in **Chapter 4**.

The gap types are:

Type A: Rolling stock replacement

Type B: Planning infrastructure and rolling stock together

Type C: Operational flexibility

Type D: Legislation.

Initial discussions with stakeholders suggested that it may be possible to generate cost savings in the procurement of new rolling stock.

Network Rail therefore sought advice from the Railway Industry Association (RIA), to understand how costs accrue in the manufacturing and procurement process.

RIA represents UK-based railway suppliers, and its rolling stock manufacturing members are Bombardier Transportation, Alstom and Siemens.

Three specific questions were asked:

- how does the length of passenger rolling stock vehicles affect cost?
- what is the variation in vehicle cost with order volume?
- what is the cost of discontinuous rolling stock procurement?

The evidence provided by RIA in response to these questions has enabled a bottom up development of the potential to generate cost savings by addressing the gaps identified.

This evidence is pertinent to several of these gaps and is therefore presented at appropriate junctures within this chapter.

In addition to this evidence the Working Group has undertaken extensive consultation with industry stakeholders to gain an improved understanding of the cost of providing new rolling stock and of the interdependencies between the business models of train builders (and their suppliers) and the activities of key industry organisations such as Government, lessors, Train Operating Companies (TOCs) and Network Rail.

5.2 Type A: Rolling stock replacement

Type A gaps are those where there is a requirement to replace ageing rolling stock or procure new rolling stock to accommodate growth. This may present an opportunity to procure future rolling stock in a more cost efficient manner.

Four gaps have been identified which relate to rolling stock replacement, they are:

Gap A1: Insufficient rolling stock to meet future growth

Gap A2: Better alignment of rolling stock replacement to match market sector needs

Gap A3: Economies of scale

Gap A4: Continuity of procurement.

Each gap has been explained in turn.

5.2.1 Gap A1: Insufficient rolling stock to meet future growth

By 2034, total national passenger demand is forecast to grow by approximately 80 per cent. This increase is expected to be stimulated by growth in employment, population and the economy. Beyond this background growth, significant additional growth may be stimulated by further improvements in rail services and other drivers of change, such as the increasing cost of private motoring.

Accommodating this growth presents a challenge to the industry.

Capacity already exists to accommodate some of this growth during off-peak periods, and to a lesser extent during the peak periods by increasing rolling stock seating density or more efficient resource allocation. However, in the medium to long term, significant additional capacity will be needed, requiring the procurement of additional passenger rolling stock to run longer and more frequent services. **Figure 5.1** shows a scenario of the current fleet, with approximately 12,100 vehicles being withdrawn from service over time as they reach the end of their theoretical commercial life. The profile excludes orders for the Intercity Express Programme (IEP), Thameslink and Crossrail. The commercial life of rolling stock tends to be 30 years for diesel vehicles and 35 years for electric vehicles and coaching stock. However, there are some vehicles within the current fleet which will be operational beyond this. On the basis of this assumption, by 2030 over half of the current fleet will require replacement, although it should be noted that rolling stock is often operated beyond this asset life with investment in life extensions and refreshes.

As discussed in **Chapter 3**, the cost of procuring rolling stock is high. Affordability plays a major part in any rolling stock procurement decisions that are made. If rolling stock costs remain high there may be a trend to consider alternative solutions or forgo the procurement of new vehicles.

Table 5.1 details the fleet size split by market sector and the average annual requirement for new vehicles based on a) no growth and b) a 1.25 per cent per annum increase in rolling stock, which is consistent with the longer term view of demand growth underpinning the Initial Industry Plan.

New vehicles may in some instances have less capacity than the vehicles which they replace. This is because of changing legislative requirements, such as the provision of accessible toilets and crumple zones, and changing passenger expectations about facilities, which reduce the available space. The impact on capacity should be considered on an order-by-order basis. Excluding these considerations, the forecast growth and the predicted removal from service of some of the current fleet, shows that given a nominal life for each vehicle of 30-35 years, there could be a need to procure over 8,000 vehicles in the next twenty years alone.

Figure 5.1 – Scenario of life expiry of the existing UK passenger rolling stock fleet

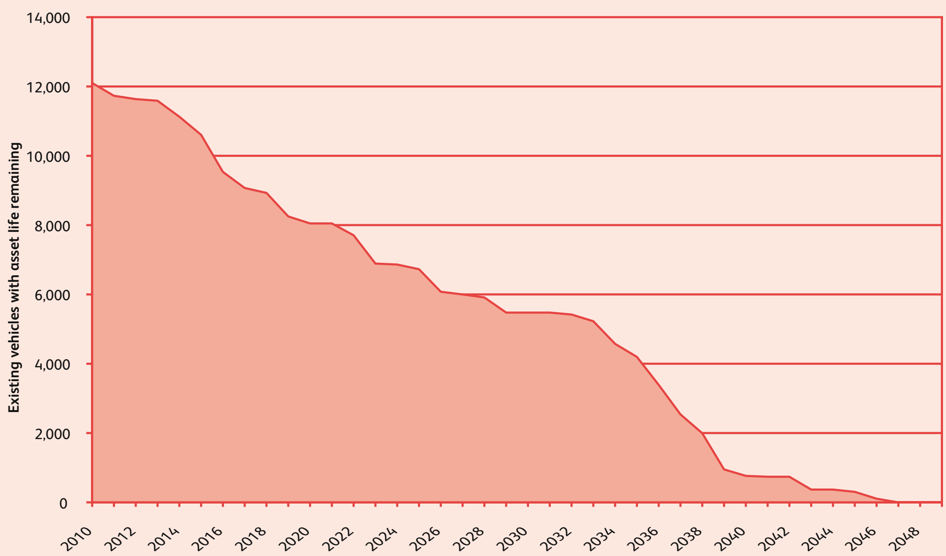


Table 5.1 – Annual vehicle replacement at selected growth rates and life expiry scenario

Market sector	Average annual vehicle replacement at selected annual traffic growth rates	
	Replacement due to life expiry only, no traffic growth (new vehicles per year 2010-2049)	Replacement due to life expiry plus additional vehicles to accommodate long-term traffic growth at 1.25% (new vehicles per year 2010-2049)
Long distance high speed	74	122
Interurban	36	62
Regional	36	60
Outer suburban	62	96
Inner suburban	163	274
Rural	11	19

5.2.2 Gap A2: Better alignment of rolling stock replacement to match market sector needs

As discussed in **Chapter 3**, each of the market sectors has different requirements of the rolling stock which serves them. Currently there are 16-20 broad types of rolling stock serving the six market sectors.

It is important that the needs of the market sectors are considered when new rolling stock is procured in order for the vehicles to remain fit for purpose over the duration of their life.

There are three principal risks that may mean that, over time, the characteristics of rolling stock become inappropriate for the market sector it serves. The first of these is where demand for travel to and from a certain station grows rapidly, for example introducing more than one market sector onto the same route.

The second is where existing rolling stock is redeployed to an alternative route following a delivery of new trains.

Thirdly, market sectors can change over time as passengers' preferences change and their perception of rolling stock varies accordingly. The Government's 2007 Rail White Paper described a future where passengers would be more affluent and there would be a high demand for rail to accommodate passengers travelling over greater distances. In the development of a market sector, new rolling stock can be introduced or existing vehicles may be overhauled in order to become up-to-date with passenger requirements. Rolling stock overhaul may involve new interior layouts being fitted as well as other technological advancements.

Gaps would occur if passenger market sector needs are not been identified before rolling stock is introduced.

5.2.3 Gap A3: Economies of scale

A significant amount of non-recurring cost investment, such as research and development, is required to produce a new type of rolling stock. This work is typically unique to each rolling stock fleet and there are few synergies between the research and development activities undertaken for different types of rolling stock. It is estimated by RIA that the cost of this work is, 'rarely less than £10 million, even for repeat orders of trains, and can reach as much as £100 million for substantially or completely new train specifications'.

As discussed in **Chapter 3**, there are 16-20 broad types of rolling stock in use over the network, each with a set of bespoke major components and associated research and development costs. Whilst some elements of the design are common to rolling stock produced for the global market, much of the design is bespoke. As a result, Great Britain has not been able to exploit potential economies of scale in rolling stock production.

Information provided by RIA suggests that reduction in the number of variants, and an increase in the number of vehicles of each variant, would reduce both the one-off research and development share of the total cost per vehicle and the average cost per vehicle. This reduction in costs would occur at a diminishing marginal rate with the additional total cost saving reducing as the number of vehicles per variant increases.

Gaps may exist where, for whatever reason, the economies of scale when procuring new rolling stock have not been exploited. High start up cost of production and small fleets of bespoke rolling stock designs increase the overall cost of rolling stock.

5.2.4 Gap A4: Continuity of procurement of rolling stock

As discussed in **Chapter 3**, in recent years the number of new vehicles ordered has not been consistent year on year. **Figure 3.11** within **Chapter 3** shows the number of new vehicles ordered each year in Great Britain since 1988 until 2010. Over this period procurement of new rolling stock has been planned around replacement of fleets upon life expiry, such as the deployment of Class 220/1 vehicles on the Cross Country franchise in 2001/02 and the Class 390 rolling stock on the West Coast Main Line (WCML) in 2002. This has led to a stop/start pattern of orders. A large bespoke order to replace a fleet has tended to be preceded or followed by several years with lower numbers of orders.

Lengthy gaps between orders have meant that once an order has been completed, train builders and their suppliers have taken a view that it is not always commercially viable to maintain the level of productive capacity that is required to meet similarly sized future orders of the same design. The result of this is that a new rolling stock order usually involves mobilisation of productive capacity from scratch. This requires procurement of industrial hardware, production line set up and staff recruitment in both train builders and their suppliers prior to the start of work. This often leads to redundancy and asset wastage once the order has been completed.

RIA has consulted with some of the vehicle manufacturers and has estimated that this increases the cost of building rolling stock for the British market by approximately 20 per cent over what would have been possible against a scenario of continuous production. This figure is exclusive of any costs incurred in the bid process.

Gaps have been identified where the discontinuous procurement of new trains increases the cost of manufacturing.

5.3 Type B: Planning infrastructure and rolling stock together to reduce whole industry, whole life costs

Type B gaps are those which relate to the planning of the infrastructure and rolling stock together, which if optimised could potentially offer future cost efficiencies in rolling stock procurement for the railway.

There are many interfaces that exist between the rolling stock and the infrastructure which it operates over. These interfaces affect both the operational performance of a vehicle as well as the experience which the passenger has. The network gauge, for example, affects where a vehicle operates. The platform/vehicle interface can affect passenger access as areas of the network are subject to variation of the platform position.

Four gaps have been identified which relate to planning the infrastructure and rolling stock together, they are:

Gap B1: Infrastructure not always planned for future vehicle designs

Gap B2: Vehicle length

Gap B3: Vehicle and network gauge

Gap B4: Platform/train interface.

Each gap has been explained in turn.

5.3.1 Gap B1: Infrastructure not always planned for future vehicle designs

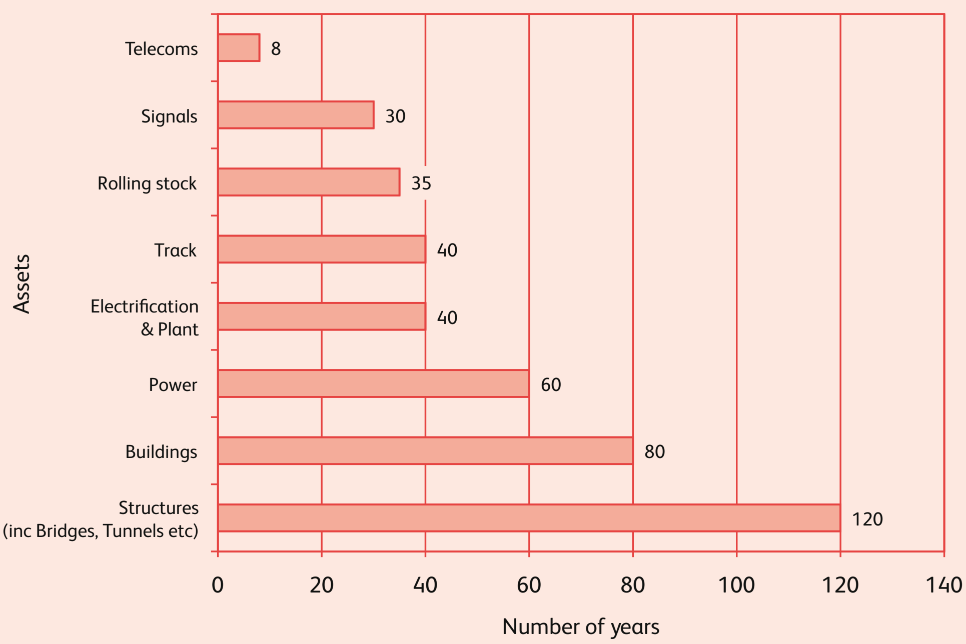
Structures such as bridges, tunnels and platforms, tend to have a longer asset life than other components of the railway system. Many bridges, tunnels and viaducts, on the network are typically over 150 years old and have seen little change since they were first constructed. This means that some of the oldest structures on the network have potentially seen at least five generations of rolling stock.

Figure 5.2 shows the typical asset life of some of the railway system components. However, there is considerable variation of asset life of the same types of structures depending on a variety of factors including construction material.

Rolling stock tends to have a much shorter asset life than the major structural components of the railway. In the past, it has been accepted that new vehicles would be introduced to match the existing capability of the routes for which the rolling stock is to be deployed. The routes which serve the market sectors are often diverse in nature and the infrastructure is often variable in its physical capabilities. This situation has led to the development of rolling stock which is designed to operate over a particular route and not widely deployable across similar routes within the same market sector.

More recently, new railways such as High Speed 1 (HS1), and reopened railways such as the route between Airdrie and Bathgate, have been designed with both future rolling stock and infrastructure in mind.

Figure 5.2 – Typical railway asset life



5.3.2 Gap B2: Vehicle length

A gap has been identified where cost efficiencies could potentially be made if vehicle lengths are optimised to achieve the lowest capital cost train configurations. RIA has identified that the costs of train manufacturing can be broadly divided into two categories:

- costs which rise in proportion to the length of the vehicle – bodyshell, seats etc
- costs which do not have a direct dependency upon length of the vehicle – bogies, cabs, air conditioning etc.

RIA has stated that although the second category of costs are not directly related to length, they are not fixed costs. The optimum choice of bogie design or air conditioning arrangement etc is not generally the same for vehicles of a differing length, even if the vehicle is intended for the same kind of service. RIA has estimated that the cost of manufacturing the following vehicles varies proportionally according to length:

- a 23 metre vehicle is between approximately 8 per cent and 12 per cent more expensive than a 20 metre vehicle
- a 26 metre vehicle is between approximately 15 per cent and 25 per cent more expensive than a 20 metre vehicle.

It is important to emphasise that all other factors affecting costs (ie those not relating directly to the vehicle configuration) are excluded[2] from the figures above.

Although longer vehicles are more expensive than their shorter equivalents, there are some instances where the overall train costs using longer vehicles for the equivalent seating capacity is less expensive. For example:

- a 10 x 23 metre train is between approximately 7 per cent and 12 per cent less expensive to produce than a 12 x 20 metre train
- a 9 x 26 metre train is between approximately 6 per cent and 14 per cent less expensive to produce than a 12 x 20 metre train.

In other words the cost saving through a reduction in the number of vehicles per train (and the associated number of expensive components), is greater than the total increase in cost per vehicle.

Gaps have been identified where efficiencies could be made in the future procurement of rolling stock by using fewer but longer vehicles delivering the equivalent seating capacity. This gap would need to be considered along with the infrastructure costs associated with the introduction of longer vehicles.

5.3.3 Gap B3: Vehicle and network gauge

Gaps exist where vehicles within the fleet cannot be used across all routes serving the same market sector due to mismatches between the vehicle and network gauge.

Many routes have a variety of loading gauges dependent on the type of structures which are present on them. There are variations throughout the network, generally arising from the building practices of the Victorian train companies. In London and the south east, for example, there are areas which have a smaller network gauge than elsewhere in the UK due to the structures and the nature of the curved track which brings particular challenges at platforms and tunnels.

There is a wide range in the costs and complexity of altering the structures that limit a routes gauging capability. Generally the most complex structures are viaducts, over-bridges and tunnels. Platforms, crossings and line-side equipment are in most cases less expensive to alter.

The network gauge plays a key part in determining how extensively vehicles are used across the UK network.

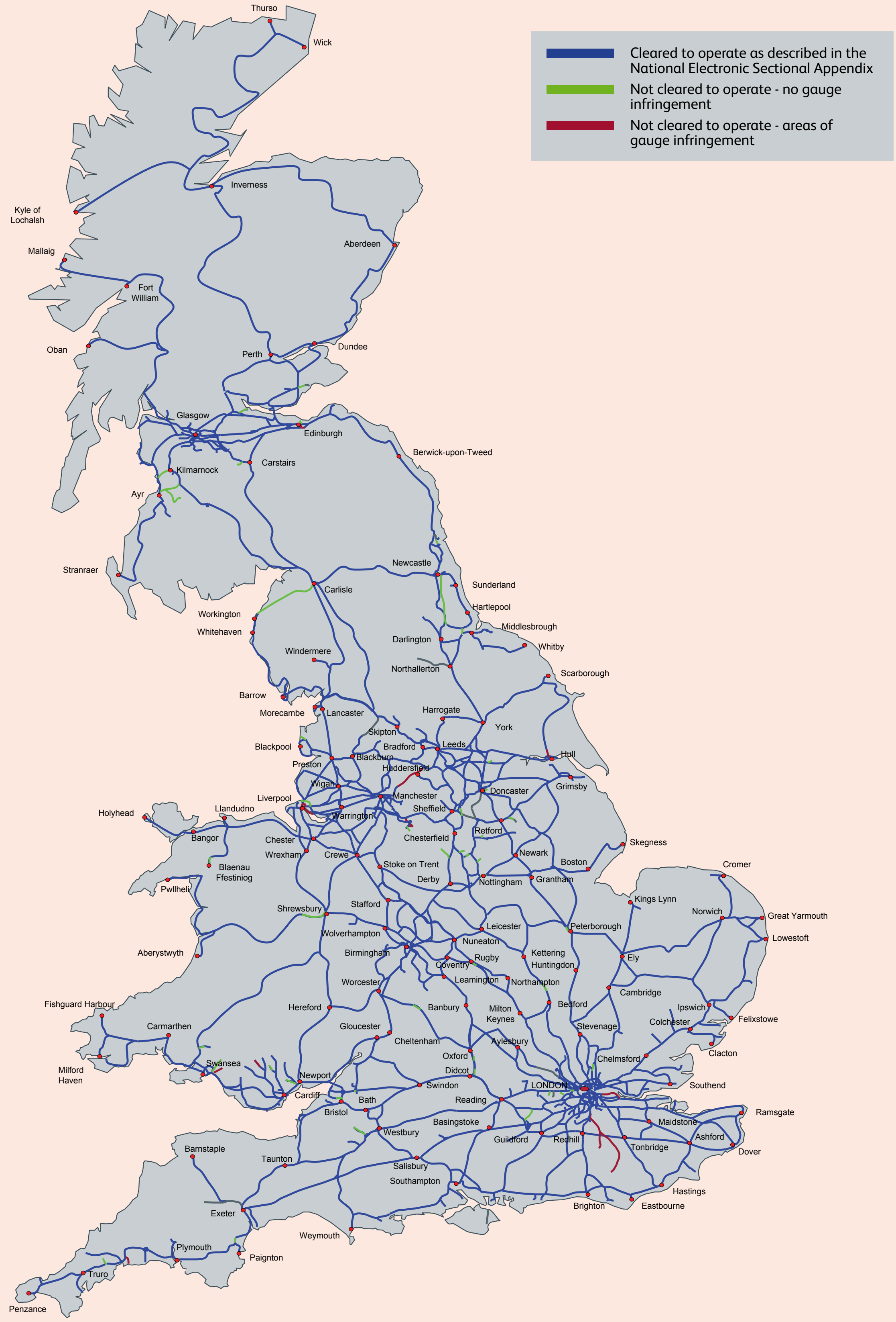
The network gauge needs to be considered along with the dimensions of rolling stock in order to understand if a vehicle is compatible with a particular route. In addition, factors such as the vehicles' dynamic performance need to be understood as this can further increase the space required between the vehicles and the structures. This is called a vehicles' kinematic envelope. Subtle differences in vehicle design can impact upon their interface with the network.

Figure 5.3 illustrates the coverage of the Mk 2 coach, which is a 20 metre long vehicle designed to be able to 'go-anywhere' on the network. The blue lines show where it is currently cleared to operate as identified within the National Electronic Sectional Appendix (NESA), the red lines show areas of the network where there are some gauge infringements and the green lines denote where the vehicle is not cleared to operate but may be able to as there are no gauge infringements. **Figure 5.4** maps the equivalent coverage of the Class 166, the high proportion of red lines shows that there are a higher number of gauge infringements.

Gaps have been identified where variations in vehicle and network gauge inhibit vehicle coverage of the routes.

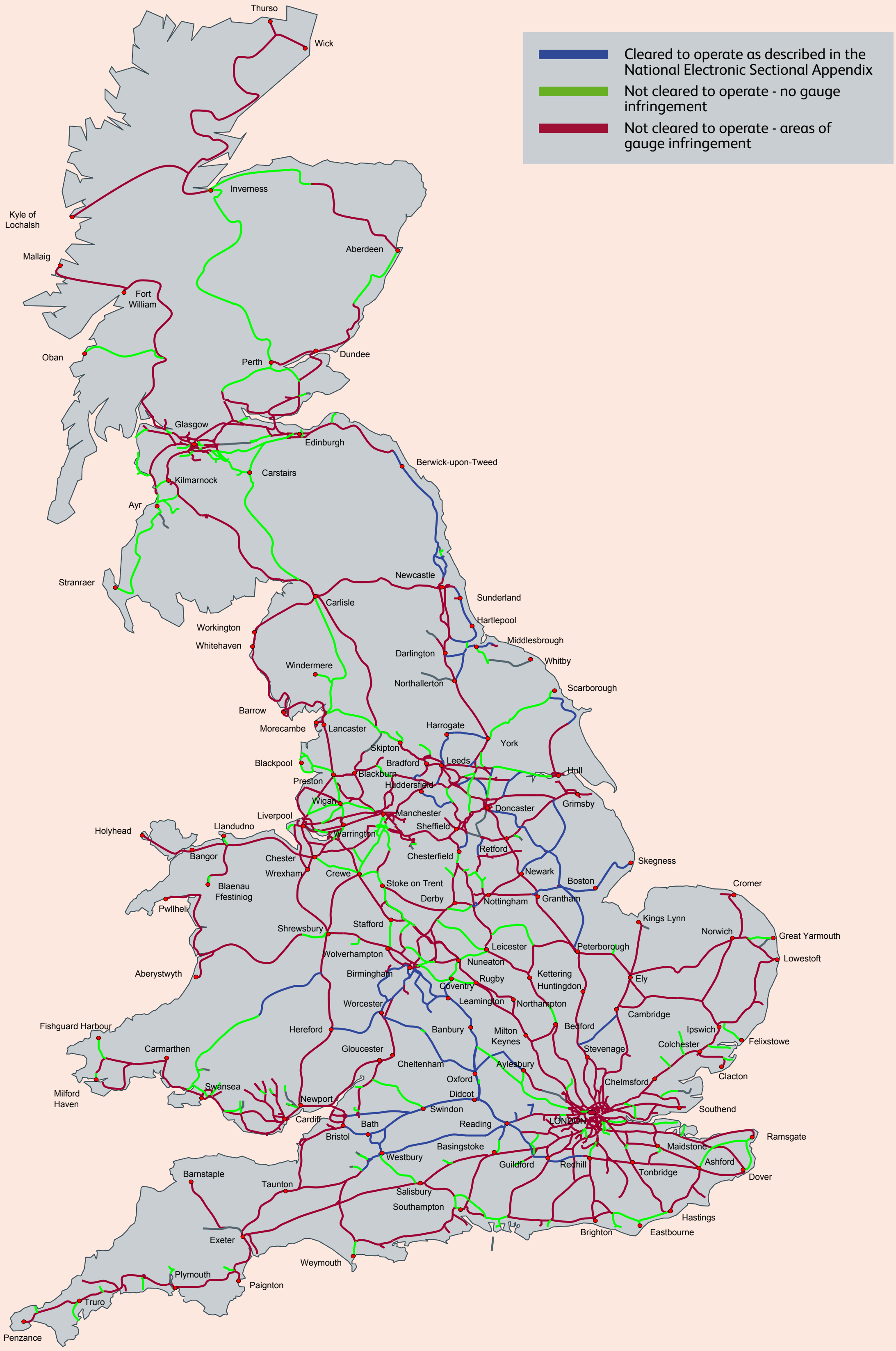
2 Specifically this includes commercial considerations and the one-off costs that apply to fleets, not to individual vehicles (such as design, development and approvals costs). The one-off cost factors were explored within Gap A3: Economies of scale.

Figure 5.3 – Routes with structures with foul or special reduced clearances to a Mk 2 vehicle



Source: Rail Safety Standards Board (RSSB), Report T787, September 2009

Figure 5.4 – Routes with structures with foul or special reduced clearances to a Class 166 vehicle



Source: Rail Safety Standards Board (RSSB), Report T787, September 2009

5.3.4 Gap B4: Platform/train interface

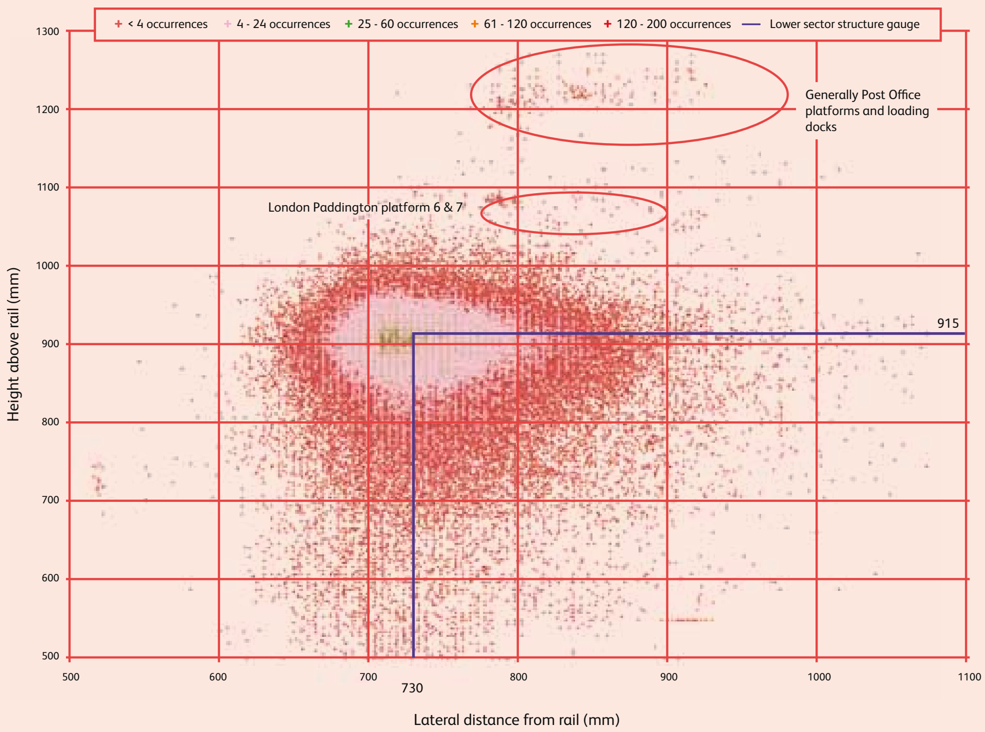
The vehicle platform interface can be considered as the horizontal and vertical distance between the train and platform. The interface is impacted by the design of the rolling stock and the platform as well as the track alignment. The following design features can impact upon the interface:

- train floor height
- position of the passenger doorways relative to the bogie
- position of a secondary step on vehicles with high floors
- platform height
- rail to platform position (lateral)
- radius of the track
- track cant.

Platforms have been developed over time to different specifications for a variety of reasons including the building practices of our Victorian predecessors, and track lowering to accommodate previous electrification programmes.

Platforms on the network vary in position relative to the adjacent track. **Figure 5.5** details the position of each platform across the whole network by plotting the height and distance from the running rail. The diagram shows the relationship between the platform edge and the rail. It plots every point along a platform (generally at 5 metre intervals); where many of these points coincide, a change of colour is used. It shows that most platforms are within the maintenance tolerance of 915 millimetres high from rail and 730 millimetres away from rail mandated for new platforms, with a few exceptions, usually single locations along a platform.

Figure 5.5 – Plot of platform edge positions across the UK network



There are a number of platforms that are high, mostly by design, such as Post Office and Heathrow Express platforms. Many more are low mainly due to track works over the years. The cluster of points has a tail to the right as lateral clearances have to be increased as track radii approach 360 metres and below.

As track radii decreases, the amount a vehicle throws increases. To allow for this, structures and platforms on tight (less than 360 metre radius) are moved away from the track. Where the radius is less than 160 metre (which is the Victorian alignment of at least 100 platforms) stepping distances become non-compliant and a large gap is present between vehicle and platform, especially for those vehicles where the door is positioned at the centre or end of the vehicle. In practice these platforms are very difficult (and expensive) to correct, usually due to the constraint that caused the tight curvature in the first place.

Other factors which can affect the platform and vehicle interface can be influenced by the market sectors which the route serves. For example, a route that serves high speed or freight vehicles may require additional clearance tolerances built into the structures to accommodate them.

Gaps exist on areas of the network where the match between the vehicle step and platform position is not optimal.

5.4 Type C: Operational flexibility

Type C gaps are those which affect a vehicle's operational flexibility. The operational flexibility of the fleet can be limited by a vehicles compatibility with other vehicles and its network coverage.

Three gaps have been identified which relate to the operational flexibility of rolling stock, they are:

Gap C1: Vehicle compatibility

Gap C2: Vehicle network coverage

Gap C3: Network electrification

Each of these gaps is explored in turn.

5.4.1 Gap C1: Vehicle compatibility

As introduced in **Chapter 3**, the number of multiple unit vehicle classes which are compatible with other types accounts for a small proportion of the entire fleet. Many classes serving the same market sector cannot couple or operate together because of differing coupling systems and train control systems. This creates a barrier to interworking of vehicles.

There are 11 classes of multiple unit which can only couple or inter-operate within the same class, they are:

DMUs:

- 171
- 185
- 222

EMUs:

- 332
- 333
- 334
- 357
- 395
- 442
- 458
- 460

A fleet that is limited in vehicle-to-vehicle compatibility can be restrictive in terms of operational flexibility. Vehicles that do not interface cannot work together in rescue situations or allow for portion working of trains, where units can be separated in service to efficiently cover routes.

The main reasons for a lack of compatibility between classes of multiple units are:

- there are several types of auto-couplers in use, although they are generally not mechanically compatible
- electronic and software systems differ between classes both in terms of train management systems and passenger information systems
- not all vehicles have the same maximum operating speed, and it is therefore necessary to limit the operational speed to that of the slowest vehicle in the formation.

Gaps exist where similar vehicles serving a market sector cannot be coupled and operated together due to dissimilar interfaces.

5.4.2 Gap C2: Vehicle network coverage

Vehicle network coverage refers to a vehicles' ability to be deployed over the routes of the network. Vehicle network coverage can be determined by the characteristics of the network, such as gauge and power supply or the design characteristics of a vehicle. Some areas of the network demand unique vehicle characteristics in order to obtain a desired performance. The WCML has significant curvature for a long distance high speed route which limit speed without a tilting vehicle design, such as the Class 390.

A number of vehicle types on the existing network have limited coverage due to their gauge; wider vehicles, such as the Class 165/166s have limited opportunities for deployment across the network. Historically there have been some vehicles developed with wide network coverage in mind.

The British Rail Mk2 coach has excellent network coverage as identified in **Figure 5.3**.

Signalling and radio communication systems can be specific to certain routes restricting the vehicles that can be operated. For example the Cambrian Line has been used as a trial for European Rail Traffic Management System (ERTMS) Level 2 which requires that the rolling stock operated on this route are fitted with Global System for Mobile Communications-Railway (GSM-R) and European Train Control System (ETCS). As ERTMS is implemented across the network, the conversion of rolling stock to allow them to operate on these routes will become a wider issue for flexibility of deployment.

The various Strathclyde EMUs were tied to their local area without conversion work, because they were fitted only with Strathclyde Manning Agreement (SMA) voice radio which was not used anywhere else. However, with the advent of GSM-R the radio is becoming standardised.

Gaps are present where the rolling stock has limited network coverage and cannot be deployed over all the routes serving a specific market sector.

5.4.3 Gap C3 – Network electrification

Approximately 40 per cent of the british rail network (measured in track miles) is currently electrified. Two-thirds is equipped with overhead line alternating current electrification, whilst the remainder of the system is predominantly third rail direct current electrification with some small local systems.

A substantial number of self powered trains run on the electrified network (a practice referred to as 'running under the wires'). This is commonly the case when a service is scheduled with an origin or destination outside of the electrified portion of the network.

It is unlikely that the electrification of some parts of the network with low value use will have an acceptable business case so a self-powered solution will continue to be required. Environmental targets for the reduction of harmful emissions and the uncertainty of the costs of domestic oil in the future demand that alternatives to diesel self propelled vehicles are sought.

Gaps exist where electric vehicles cannot be used as extensively over the network as operators may wish because of the extent of existing electrification.

5.5 Type D: Legislation

Type D gaps are those that arise from the introduction of new or changed legislation.

Two gaps have been identified which relate to legislation, they are:

Gap D1: Accessibility

Gap D2: Carbon and emissions

Each gap has been explained in turn.

5.5.1 Gap D1: Accessibility

The legal deadline for all rolling stock to be accessible is significant for rolling stock operators. Whole vehicle classes would require major overhaul works or face removal from the network. Others will require minor modifications to bring them into line with the regulations.

Gaps exist where some vehicles within the current fleet require modification in order to become compliant by 2020.

5.5.2 Gap D2: Carbon and emissions

The fuel quality directive sets the maximum permitted sulphur limits in fuel. The directive will see a move to sulphur free diesel by January 2012. It will also bring with it a minimum blend specification for biofuel.

The Non-Road Mobile Machinery Directive (NRMM) sets engine exhaust emissions limits for new engines for non-road applications, including rail. This will require increasingly stringent standards for new engines, including new replacement engines.

Gaps may be present in the future where the affordability of using diesel powered rolling stock requires alternative power solutions to be considered.

5.6 Summary of the gaps

Table 5.3 summarises the gaps which have been discussed within this chapter. **Chapter 6** goes on to discuss options which address these gaps.

Table 5.3 – Summary of gaps

Gap ID	Gap name	Driver of gap
		Type A gaps – Rolling stock replacement
A1	Insufficient rolling stock to meet future growth	The fleet is ageing Additional rolling stock will be required to accommodate the forecast increases in passenger numbers New rolling stock costs are high and may not be affordable
A2	Better alignment of rolling stock replacement to match market sector needs	There is not a high level specification that matches the passenger needs of each market sector with the infrastructure, such a specification only relates to the vehicle network interface
A3	Economies of scale	Comparatively small orders of bespoke rolling stock result in a higher cost High start-up costs for vehicle production runs
A4	Continuity of procurement of rolling stock	Lengthy gaps between the rolling stock orders

Table 5.3 – Summary of gaps

Gap ID	Gap name	Driver of gap
Type B gaps – Planning infrastructure and rolling stock together		
B1	Infrastructure not always planned for future vehicle designs	Lack of co-ordinated planning of the rolling stock and the infrastructure can be costly
B2	Vehicle length	Variety of vehicle lengths serving the market sectors Longer vehicles may offer opportunity to reduce the capital cost of a train
B3	Vehicle and network gauge	Network gauge variations across routes serving a similar market sector Variety of the vehicle sizes which have been developed for particular routes – this manifests into vehicle cascade difficulties Vehicles deployed across the network can vary in size and shape in order to be compatible with the gauge
B4	Platform/train interface	Vehicle and platform interfaces vary due to the historical development of platforms and a variation of rolling stock step positions Over the network there are some areas which have a mismatch between the vehicles and the platforms causing large gaps, high or low stepping distances
Type C gaps – Operational flexibility of rolling stock		
C1	Multiple Unit Vehicle compatibility	Some multiple unit vehicles serving a market sector cannot be coupled and operated together due to dissimilar interfaces
C2	Vehicle network coverage	Vehicles serving a single market sector are often not able to operate over all the sectors routes Electric vehicles cannot be used over the non-electrified network Gauge restrictions In-cab signalling or radio system compatibility may restrict the routes on which vehicles can operate
C3	Network electrification	Increase the operational flexibility of electric rolling stock Diesel vehicles are less desirable on environmental and cost grounds
Type D gaps – Legislation		
D1	Accessibility	Introduction of legislation may require that some of the existing vehicles are modified in order to remain in service
D2	Carbon and emissions	Non-Road Mobile Machinery legislation will set targets for exhaust emissions for new engines fitted to rolling stock including replacement engines on old rolling stock. Fuel quality directive which sets the maximum sulphur limits. In the short term this will see a move to sulphur free diesel Noise directives which requires Member States to produce noise maps and action plans for major transport infrastructures including railways

6. Options

6.1 Introduction

This chapter discusses options identified to address the four categories of gaps discussed in **Chapter 5**. In each case, the option selection process was undertaken with the aim of reducing the whole industry whole life cost of passenger rolling stock, and the infrastructure, as well as meeting the passenger requirements of each market sector.

Options have been grouped into categories and a series of matrices are used to show which gaps each option addresses.

The categories that the options have been grouped into are as follows:

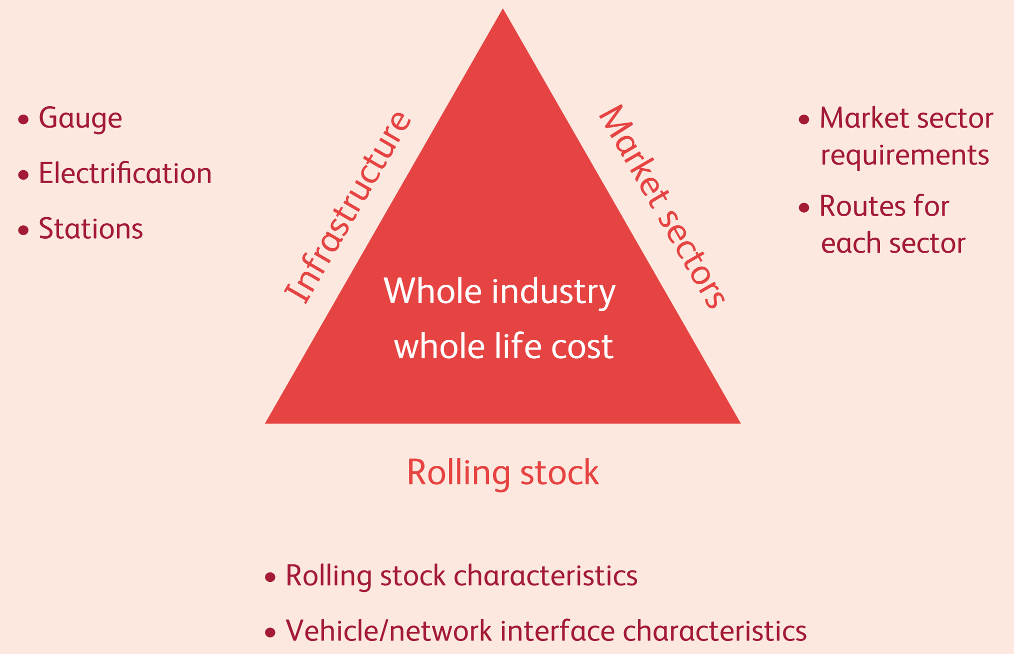
1. **life extension of existing vehicles** – this option considers the factors which influence the decision to selectively life extend vehicles
2. **economies of scale and efficient procurement of rolling stock** – these options consider the potential savings which could be achieved if it were possible to purchase rolling stock in sufficient volumes and smooth the procurement over time to deliver economies of scale. Consideration is given to how this could be exploited without creating monopoly suppliers or diminishing the advantage of commercial negotiations
3. **meeting the needs of the market sector using fewer types of rolling stock** – this option considers the passenger and operational needs of rolling stock in each market sector. In particular it considers those aspects of vehicle design which interact with the infrastructure
4. **planning the infrastructure together with rolling stock** – these options set out the infrastructure considerations that would be required to ensure that rolling stock identified for a particular market sector can operate where it is needed
5. **options addressing legislative change** – these options relate to the gaps which may arise through the change in legislation affecting accessibility and environmental considerations.

The overarching theme of options is the exploration of the efficiencies that could be achieved from considering the nature of rail's market, the rolling stock that serves it and the infrastructure together. The inter-relationships are shown in **Figure 6.1**.

Varying one factor has an impact on the other two elements. For example, if market sector needs change, this may require rolling stock with different characteristics, which in turn may result in differing requirements from the infrastructure. All of the gaps identified have an impact on more than one of the three factors in the diagram. Similarly, options have been considered in this context.

The options considered in this chapter have been set out in turn to build upon each other and are then combined into an appraisal at the end of the chapter. The appraisal discussed in **Section 6.7** combines those options that are dependent upon each other to allow the whole industry whole life cost benefit to be assessed. The options have been combined for appraisal as it is not logical to assess them in isolation from each other because of the close relationship between the factors which influence whole industry whole life cost.

Figure 6.1 – Relationships comprising whole industry whole life cost



6.2 Option to life extend existing vehicles

As discussed in **Chapter 3**, rolling stock has traditionally been considered to have a nominal commercial life of 30 year for diesel powered vehicles and 35 years for electric powered vehicles for planning purposes. Rolling stock owners and operators suggest that extending the commercial life of rolling stock can offer a cost effective means to maintaining the overall fleet size.

Table 6.1 summarises which gaps are addressed by this option.

Table 6.1 – Option to life extend existing vehicles

		Type A gaps – Rolling stock replacement				Type B gaps – Planning infrastructure and rolling stock together				Type C gaps – Operational flexibility of rolling stock			Type D gaps – Legislation	
		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	D1	D2
1.1	Vehicle life extension	X		X	X									

Option 1.1 – Selective life extension of rolling stock

Recent technical research has established that, in many instances, the life of rolling stock can be extended beyond the commercial life that was assumed upon its introduction. Where rolling stock life extension is the minimum whole life cost option, it should be considered in alongside the option to purchase new stock. The individual circumstances of each renewal will inevitably effect whether it is a cost-effective option.

The following factors need to be addressed on a case by case basis:

- can the rolling stock's life be extended technically?
- would life extension be appropriate to meet the changing needs of the market sector it serves?
- if so would life extension be the most appropriate whole life solution? And would life extension make sense commercially to the operators including capital rentals, maintenance, revenue, adaptations for Rail Vehicle Accessibility Regulations (RVAR) compliance and operational costs?

6.3 Options to achieve economies of scale and efficient procurement of rolling stock

As discussed previously, the size of the UK rolling stock fleet will be required to increase significantly over time to accommodate increasing passenger numbers. Based on the central demand projections detailed in the Initial Industry Plan it is estimated that in order to accommodate demand the UK fleet would have increased to around 16,700 vehicles by 2041. This is equivalent to an increase of almost £1.1bn per annum (in 2010/11 prices), or a 54 per cent increase in the total cost of Rolling Stock procurement and operation.

This projected increase in cost assumes no real increase in the cost of rolling stock, however this does not reflect stakeholders' recent experience of new train procurement, where the new stock has been typically more expensive than that which it has replaced. There are a number of reasons for this, in particular:

1. those fleets which were previously owned by British Rail were leased at privatisation using administratively set prices. There have been changes in the cost of capital, raw materials and residual value since then
2. new trains have a significantly higher level of equipment specification than older stock. They typically include facilities such as air-conditioning, electronic customer information systems, and accessible toilets for mobility-impaired passengers. Design and provision of trains with this equipment adds cost to the manufacturing process
3. although there have been many orders placed, particuarly as a consequence of Mk 1 replacement, many of new rolling stock orders since privatisation have been built to bespoke specifications, with significant differences between even the variants of trains made by the same manufacturer. There are a number of reasons for this, including infrastructure limitations, varying customer requirements and differences in manufacturers' practices, however the combined impact is an absence of the types of savings outlined in **Chapter 5.**

Table 6.2 – Options to achieve economies of scale and efficient procurement of rolling stock

		Type A gaps – Rolling stock replacement				Type B gaps – Planning infrastructure and rolling stock together				Type C gaps – Operational flexibility of rolling stock			Type D gaps – Legislation	
		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	D1	D2
2.1	Achieving economies of scale	X	X	X	X	X				X	X	X		
2.2	Smooth the procurement profile by life extension or withdrawing current rolling stock from service early	X		X	X									

In aggregate, it is estimated that the cost of a new vehicle is around 50 per cent greater than that of an existing variant. If this were to be combined with the requirement for more trains to accommodate passenger demand, it is estimated that by 2031 the total UK annual cost of rolling stock will have increased from £1.8bn to £3.1bn, a 72 per cent rise.

The analysis presented considers the potential for reducing the cost of the procurement of new rolling stock regardless of when it is procured, although a trajectory based on the estimated life of assets has been assumed to inform the potential saving.

Options have been developed which seek to achieve economies of scale in procurement. **Table 6.2** summarises the options and identifies the gaps which they address.

Option 2.1 – Achieving economies of scale

As discussed in **Chapter 5**, the evidence collected by the Rail Industry Association (RIA) suggests that non-recurring costs for each order range from £10 million to £100 million. This is a wide range so Network Rail has produced an iterative estimate based on the number of generic types of vehicle in operation and the known annual leasing cost and asset life.

There are approximately 64 classes of train currently in operation in the UK passenger fleet. It is very difficult to categorise these 64 classes into generic types of sufficient commonality to share both research and development costs and manufacturing production lines to act as a base case for analysis. However, with support from manufacturers who have a greater understanding of the drivers of research and development costs, it is estimated that there are 16-20 distinct types. The non recurring cost of replacing 16-20 types is estimated at around £70m per order.

Economies of scale in fixed costs such as research and development can only occur if these costs are shared over a greater number of vehicles types than the circa 190 implied by the current fleet of 12,100 vehicles spread over 64 types. (Although some of this could occur naturally through an increase in the size of the total fleet to meet growth in passenger numbers).

In order to understand the magnitude of efficiency which may be obtainable by addressing economies of scale, it is estimated that the number of types of rolling stock could be reduced from the current 16-20 broad types to around five. This is discussed further in **Section 6.4** of this chapter.

Discussions with manufacturers and rolling stock leasing companies suggest that this reduction would apply to the cost of maintenance as well as the cost of leasing, as the cost of replacement parts largely reflects the cost of building the trains they fit.

Option 2.2 – Smooth the procurement profile by life extension or withdrawing current rolling stock from service early

As discussed in the **Chapter 5**, the discontinuity of train orders, that is the large variability in the order profile from one year to the next, years with few orders, and deferral of investment decisions, requires significant mobilisation and demobilisation of the supply chain at the start and end of each order. Manufacturers report that this imports a significant level of cost into the procurement of new vehicles, which is passed through to the end customer.

Chapter 5 outlined that manufacturers believe they can obtain cost efficiencies in manufacturing if rolling stock were ordered on a more consistent and continuous basis. The manufacturers suggest they could deliver these savings if the planning and procurement processes delivered the following:

- orders for new trains of sufficient size and duration to justify the sunk costs of setting up and maintaining a production line. Namely around 150 vehicles per annum, for a number of years
- sufficient clarity in the UK-wide long-term planning of new rolling stock to justify retaining this production line when it is not in use
- a sufficient quantity of orders for new trains, and continuity in the size of these orders, such that staff can be switched from one production line to another once an order has been completed, without the need for significant increases or decreases in this manpower.

In theory it would be possible to remove this additional cost by spreading orders for new rolling stock such that the producer of each generic type of train has a sufficiently certain order of rolling stock over a period of several consecutive years. This could, in theory be achieved by:

- reducing the number of existing train variants from the current 16-20
- earlier replacement and/or life extension of rolling stock that these generic types of train would replace in order to spread the order evenly over time.

It is likely that both early replacement and life extension of rolling stock would increase the average cost of rolling stock leasing and maintenance, albeit by a potentially lower cost than the procurement of new trains.

Early replacement of rolling stock would shorten the period of time over which the asset owner can recover the cost of purchasing rolling stock, and this would be reflected in the price per vehicle. It is anticipated that earlier replacement of rolling stock would increase the annual cost over the life of the rolling stock.

Life extension of rolling stock may involve the complete replacement or the overhaul of major components which have worn out. Recent evidence suggests that this increases the cost of the rolling stock over the remaining extended asset life. The true cost of life extending a vehicle would, in part, be dependent upon where it is within its maintenance cycle. However, life extension of rolling stock may yield savings by delaying procurement of new vehicles.

These savings are dependent on the baseline assumption of how the fleet is expanded to meet underlying demand growth. If the number of generic types of rolling stock increases with no change to the current number of vehicles per variant, then the potential saving identified above would be achieved. If the number of generic types of rolling stock remains the same with an increase over the current number of vehicles per variant, then the saving through this option would be smaller. This is the converse of the potential for economies of scale.

Whilst the savings from continuous production are potentially large, they are only part of the story when considering procurement efficiencies. There will be a healthy competitive tension between procurers and manufacturers to drive commercial deals, and there will also be healthy commercial competition between the different manufacturers. In both cases, the commercial competition would be expected to drive down costs.

6.4 Options to meet the needs of each market sector with fewer types of rolling stock

Options 2.1 & 2.2 consider the efficiencies that can be obtained through economies of scale and managing a smooth procurement profile. In order to achieve this it was suggested in Option 2.1 that the reduction of rolling stock types may reduce the non-recurring costs associated with each order. This option takes this concept a step further and considers the market sector needs of the rolling stock which serves them in order to reduce the variation of rolling stock procured. **Table 6.3** highlights the gaps which are addressed by this option.

Table 6.3 – Options to meet the needs of each market sector with fewer types of rolling stock

		Type A gaps – Rolling stock replacement				Type B gaps – Planning infrastructure and rolling stock together				Type C gaps – Operational flexibility of rolling stock			Type D gaps– Legislation	
		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	D1	D2
3.1	Reducing market sector types	X	X	X	X	X				X	X	X		

Option 3.1 – Reducing market sector types

A simplified market sector led definition of rolling stock types could assist with any future procurement strategy by enabling economies of scale. Economies of scale may result from greater degrees of standardisation in the basic physical characteristics of the rolling stock. A high-level specification for rolling stock that considers the needs of each market sector would help ensure that new rolling stock meets the passenger and operational requirements. This could draw on the approach illustrated by recent schemes such as Thameslink and Intercity Express Programme (IEP) where Passenger Focus managed a survey of passenger requirements to assist with the development of the future rolling stock specification. The Department for Transport (DfT) developed this approach further by announcing that relevant Train Operating Companies (TOCs) will be involved in the detailed design of IEP.

There are two elements which drive a variation in the types of trains produced, these are:

- **passenger market sector requirements** – Namely, the essential operating requirements relative to the market sector a train serves, including speed, acceleration, door positioning, and minimum equipment level, such as toilets, customer information screens and sound proofing
- **technology and interface with the infrastructure** – Namely, variations from the most recently produced train in a market sector, driven by a preference for different on board equipment and/or infrastructure constraints.

The variations in the second category are driven by customer preferences these relate to a desire for specific equipment and layout of this equipment. For example the type and positioning of customer information screens, rather than the existence of this equipment in the first place which is driven by the market sector requirement. Development of a single equipment specification for each train type is a key recommendation of this strategy.

Variations that are driven by infrastructure constraints such as vehicle length, gauge, and traction power do not fundamentally alter the commonality between sub-types of train, providing they are specified in advance of the design process, and do not involve a major innovation or change in the level of technology employed. However, reducing the number of these variations would have the potential to lower the cost of new rolling stock, and the standardisation of infrastructure specifications is designed to exploit this potential when combined with the common train specifications.

Chapter 3 describes the basic attributes of each market sector and the rolling stock that is currently deployed to serve it. The RUS has undertaken high level development of a specification for rolling stock which addresses the gaps which were identified where there was a mismatch between rolling stock and infrastructure. The option considers whether standardisation of the size of new rolling stock which is introduced to the network would make future cascades and vehicle deployment simpler.

Considerations of the market sectors in turn suggest that a more standardised fleet serving each market sector could be achieved as follows:

- ***outer suburban*** – replacement of the existing rolling stock with a single variant of trains could increase the average number of vehicles per variant serving the sector from around 700 to nearly 6,000. A rolling stock variant of this quantity and a continuous order profile could, in theory, generate almost the maximum achievable unit cost saving through economies of scale and continuous production
- ***interurban*** – this market sector is currently served by around 1,200 vehicles. Both the outer suburban and inter-urban sectors share minimum operating requirements relating to speed, acceleration, equipment level and door layout. Therefore if it were possible to agree a standard set of customer requirements, one single specification of train type could be used for new train procurement in both market sectors
- ***regional*** – there are around 1,100 vehicles serving this sector and although it shares many of the minimum operating characteristics of the outer-suburban and inter-urban sectors, the minimum equipment requirement is more basic. Therefore, it would be more suitable to develop a single specification of train type to serve this sector
- ***rural*** – taken alone this market sector is too small to exploit the potential savings identified above. However, it would be possible to use a single variant of rolling stock specified for one of the other sectors previously discussed to meet the key requirements of this market. A variant may share similar characteristics such as body shell and traction package.

The rural sector is typically served by older stock that is cascaded from another route following a delivery of new trains. Given the minimum required operating characteristics, this stock is likely to originate in the regional sector. This means that over time both the regional and rural sectors could share a single specification.

- ***inner suburban*** – this market sector comprises of around 1,700 vehicles, it is sufficiently large that specification of a single generic type of train to serve it could generate unit cost savings

- ***long distance high speed*** – the rolling stock that is required to serve this market sector is unique in terms of both the operational speed and passenger accommodation. Two key factors will influence how this market is served and whether there can be a reduction in rolling stock types:
  - The planning process to replace the existing High Speed Train (HST) fleet is underway and the future design or designs, are likely to be influenced by this
  - high speed tilt enabled vehicles are used on the West Coast Main Line (WCML) in order to achieve faster journey times. This type of rolling stock is significantly different from rolling stock that does not have this capability and it may not be cost-effective for all long distance high speed rolling stock to share this specification.

Operating requirements in the long distance sector vary by maximum speed, emerging traction technology, and the ability to tilt, and even with a single set of customer requirements, the minimum number of train specifications possible is around five.

Table 6.4 details the high-level rolling stock requirements for the market sectors and introduces the five rolling stock types. It is envisaged that manufacturers and customers would agree the specification for each type up front to avoid costly alterations during the design and production process.

Table 6.4 – Market sector rolling stock requirements

Market sector vehicle type	Maximum speed (mph)	Acceleration	Traction power requirements	Vehicle length (m)	Minimum equipment level*	Door layout
Type 1 – Long distance high speed	125 - 140	Standard	25kv electric Self powered Bi-mode	23 or 26	Very high	End
Type 2 – Long distance high speed (tilt variant)	125 - 140	Standard	25kv electric Self powered Bi-mode	23 or 26	Very high	End
Type 3 – Inter urban and Outer suburban	100 (occasional 125)	Standard	Dual voltage Self powered	20 or 23	High	Market decision on door position
Type 4 – Regional and Rural	Up to100	Standard	Dual voltage Self powered	20 or 23	Basic	Market decision on door position
Type 5 - Inner suburban	Up to 90	High	25kv electric Dual voltage Self powered Bi-mode	20 or 23	Basic	Market decision on door position

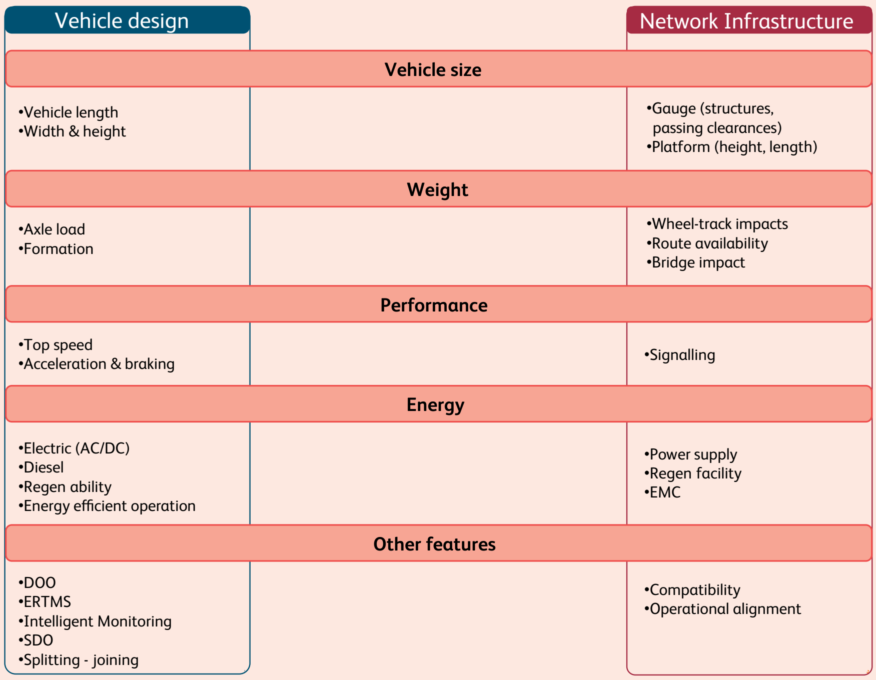
* a homogeneous equipment level and layout within each type

6.5 Options to plan the infrastructure and rolling stock together

Rolling stock and infrastructure cannot be considered as distinct separate systems. In reality they are interdependant. In order to optimise them both in operations, service and whole life terms it is necessary to plan them together.

Figure 6.2 illustrates the interdependency between elements of the rolling stock on the infrastructure. This illustrates that where a factor such as axle load of rolling stock is altered there are implications for the track alignment, route availability and on structures over which rolling stock operates. It is desirable to plan both the design of the rolling stock and any modifications to the infrastructure together to ensure that the interfaces are optimised in terms of whole industry whole life costs.

Figure 6.2 – Impact of vehicle design on infrastructure requirements



There are existing examples where such changes to the infrastructure and rolling stock have been planned strategically together. For example IEP and the electrification strategy for the Great Western Main Line (GWML) have been developed in tandem.

In this case, the considerations of the two elements together had a number of benefits, potentially reducing whole life costs for GWML, resulting from electrification and the introduction of high capacity trains.

The accuracy and availability of infrastructure data is also of key importance to rolling stock manufacturers to enable the design of optimised interfaces.

It is recommended that development of both the infrastructure specification and common train specifications seek to identify the other interdependencies between other elements of vehicle design and infrastructure provision and maintenance, in order to minimise the whole life cost of both.

When considering the design and deployment of rolling stock it is important to consider the following interfaces:

- ***wheel/rail interface*** – the performance of this interface is influenced by both the vertical loads it has to support and the suspension characteristics of the vehicle bogies. Careful attention to vehicle design, ensuring that the vehicles are suited to the routes over which they will operate, and that they minimise wear and damage to the track, can therefore help to maximise rail life and reduce costs.

  Whilst vertical loads will tend to increase as the vehicle length increases which will increase the rate of track geometry degradation. The suspension design will influence the forces responsible for wheel and rail surface damage such as rolling contact fatigue cracks and wear. Factors which should be considered to optimise the interface include:

- ***axleload:*** this should be reduced as much as possible. The damage caused by an increase in axleload as vehicle length increases may be offset by a reduction in the number of axles causing damage
- ***unsprung mass:*** the impact from components which are below the vehicle suspension, such as wheels, axles and brake gear can be a significant contributor to track degradation, but can be reduced by reducing their mass: for example the use of smaller wheels or hollow axles
- ***bogie suspension:*** reducing the stiffness of the plan-view bogie suspension can reduce the wheel/rail forces, extending wheel and rail life, but if not properly optimised can lead to a reduction in ride quality. The use of emerging technology, such as variable stiffness hydraulic radial arm bushes, should be encouraged as this can reduce wheel/rail forces whilst maintaining high speed stability and ride quality
- ***wheel profile:*** careful selection of appropriate wheel profiles for the vehicle suspension design and operating route characteristics will also improve the interface.

The whole life costs and impact on the infrastructure of these parameters for new or modified vehicles can be assessed using industry modelling tools such as VTISM (the Vehicle Track Interaction Strategic Model) and Network Rail's Track-Ex software. Benefits of improved wheel/rail interfaces can be passed onto train operators through reduced track access charges. VTISM has already been used to help assess the impact of the new IEP and Thameslink trains. Reduction of the wheel/rail forces will not only accrue benefits for the infrastructure, but should also reduce wear and damage to the wheel, reducing wheelset maintenance and extending wheelset life.

- ***route availability*** – typically the maximum axle load of the train that can be accommodated on a route. Route availability for passenger rolling stock is normally only limited on the most lightly used branch lines. The design of the future rolling stock should consider the infrastructure it is required to operate over. Infrastructure should always be planned to consider the future rolling stock types and where the infrastructure is constrained considerations to adapt the infrastructure for the new types of rolling stock may be made
- ***gauge*** – the physical clearance between vehicles and structures close to the track. Network Rail has assessed the likely minimum, average and maximum infrastructure cost of the work required to accommodate standard vehicle variants across multiple route sections and market sectors, based on gauge clearance data for a range of existing vehicle types
- ***platform length*** – the minimum length of platform required to accomodate the passenger carrying vehicles. The length of vehicles and their subsequent formation needs to be considered against the routes where they are to be deployed
- ***platform stepping distances*** – the distance between a train door step and the platform is affected by vehicle length, the position of the door and the radius of the platform. Longer vehicles serving platforms with tight radii may have increased stepping distances. The position of vehicle doors presents a challenge on both concaved and convex platforms where it is difficult to optimise for both designs.

The options set out in **Table 6.5** seek to address some of the critical interfaces which need to be considered in order to enable fewer types of rolling stock to operate.

Table 6.5 – Options to plan rolling stock and infrastructure to meet future requirements

		Type A gaps – Rolling stock replacement				Type B gaps – Planning infrastructure and rolling stock together				Type C gaps – Operational flexibility of rolling stock			Type D gaps – Legislation	
		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	D1	D2
4.1	European gauge and/or double deck rolling stock	X	X	X	X	X	X	X	X					
4.2	Optimise the vehicle and network gauge appropriately to obtain maximum coverage of market sector	X	X	X	X	X	X	X	X		X			
4.3	Optimise vehicle length	X		X			X							

Option 4.1 – European gauge and double deck

This option considers whether the introduction of double deck rolling stock and european gauge vehicles would provide a cost effective solution to meeting demand.

a) Double deck rolling stock

Double deck vehicles are used across continental Europe for many services, including long distance high speed and outer suburban. They can offer increased passenger carrying capacity. However, infrastructure considerations are important as the vehicles have a greater height than standard passenger rolling stock which is operational in Great Britain. Double deck trains can also be subject to higher dwell times as the increased number of passengers board and alight.

A Network Rail and DfT led study in 2007 which considered whether double-deck rolling stock would be appropriate on existing outer suburban routes on the network was used to inform the option appraisal.

Generally double deck vehicles across Europe are 26 metre long and follow the UIC reference profile shown in **Figure 6.3** compared to the Great Britain Lower Sector Vehicle and Structure Gauges. If Britain was to adopt such a vehicle it would require the wholesale reconstruction of all stations to make them compatible with the required UIC reference profile.

Likewise, the distance between the tracks would need to be much wider in order to accommodate the wider vehicles gauge and therefore would require reconstruction of a substantial number of bridges and tunnels. The double deck trains would also be incompatible with under bridge girders and some types of signalling equipment that would also be foul of UIC gauge. Even if the infrastructure work was affordable, it would be impractical because any associated adjustments to platforms would then be incompatible with conventional rolling stock, used across Britain, as the stepping distance would be significantly in excess of the current maximum requirements set for the network.

Given the constraints across the railway infrastructure, the study considered a double deck vehicle which was able to use standard platforms used across the network and was of 23 metres in length. This precluded continental european double deck vehicles which are typically 26 metres long and have lower floor heights than vehicles used in Britain.

These constraints on the proposed double deck vehicle size (width, height and length) result in relatively little increase in seating capacity, that is around eight per cent in a 20 metre vehicle or 24 per cent in a 23 metre vehicle. These compare with increases of around 50 per cent for a ‘typical’ european gauge vehicle of 26 metres.

It was estimated that the costs of route conversions would range from £500 million to around £1.3 billion with civil engineering works accounting for the majority of this cost.

The option to use this type of rolling stock on the network was therefore discounted both on grounds of affordability and the resulting lack of operational flexibility of such vehicles.

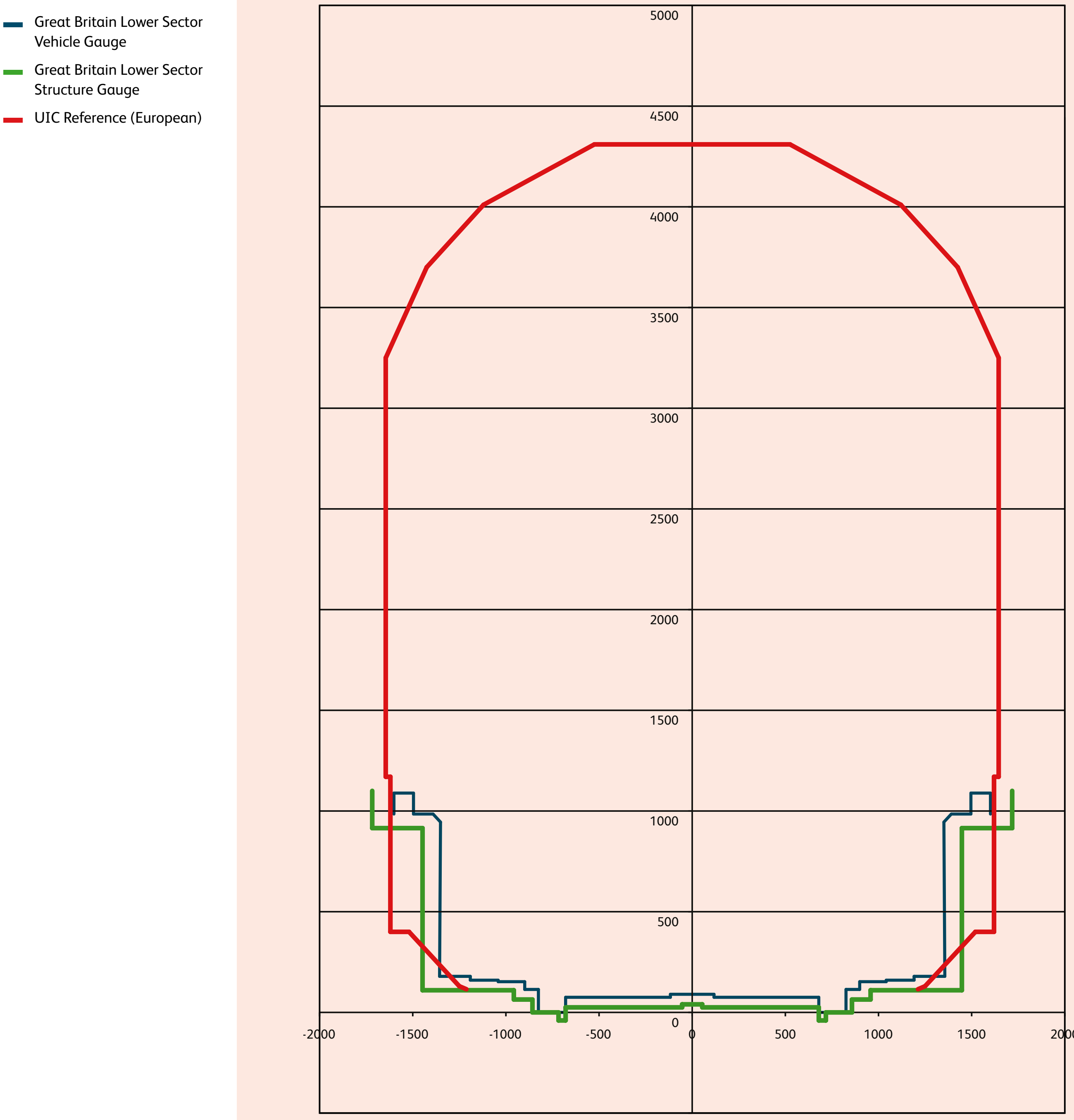
It was concluded that a double deck solution on the existing network would generate relatively low volumes of additional capacity. The benefits would not offset the costs, the significant disruption required to adapt the routes and the resulting long term inflexibility of operation. Nonetheless double deck trains could be a viable solution for a new build route where a more efficient vehicle size could be specified for a larger loading gauge.

b) European gauge rolling stock

The RUS considered whether it would be plausible to purchase off-the-shelf european gauge rolling stock for the british market to benefit from procurement savings. As discussed, continental european railways represent a larger market than the british railway and consequently european vehicle prices reflect lower unit costs. The vehicles are larger so fewer are required to carry the same number of passengers when compared with current rolling stock operating within Britain. In theory, purchasing rolling stock on the back of other larger orders may appear a plausible way of reducing rolling stock costs. European vehicle orders are generally for larger fleets and in theory relatively small orders from Britain as an add-on appears economically attractive.

However, as discussed, european gauge vehicles tend to be much wider in the lower body than vehicles used in Britain. **Figure 6.3** demonstrates a UIC reference european gauge plotted to scale against the commonly used british lower sector structure gauge and vehicle gauge. It is clear to see that the lower sector structure gauge becomes foul with the european UIC gauge. Introducing european rolling stock would therefore require a mass rebuild of existing lower sector structures such as platforms and bridge girders along with the widespread need for slewing of track. As described in the section on double deck vehicles, the cost of such a mass rebuild is very high and if changes were made to the infrastructure those areas of the network would become incompatible with existing vehicles operating on the network. The option of purchasing off-the-shelf european rolling stock was therefore discounted.

Figure 6.3 – UIC Reference (European) gauge comparison with Great Britain lower sector stucture and vehicle gauges



Option 4.2 – Optimise vehicle and network gauge

The conclusion of Option 4.1 is that european gauge and double deck vehicles are unlikely to be cost effective given the infrastructure configuration of the network. For this reason it is not proposed to further appraise the possible option to adapt the network to accommodate european gauge rolling stock. Instead Option 4.2 considers whether it may be possible to optimise the vehicle and network gauge in order to achieve greater vehicle coverage.

The strategy has considered the impact of expanding the coverage of vehicles that are 23 metre in length across the entire network through the development of a standard kinematic gauge. Whilst much of the network is already cleared for 23 metre trains to run, certain sections of the network, such as parts of the former Southern region, are only gauged for the operation of 20 metre vehicles.

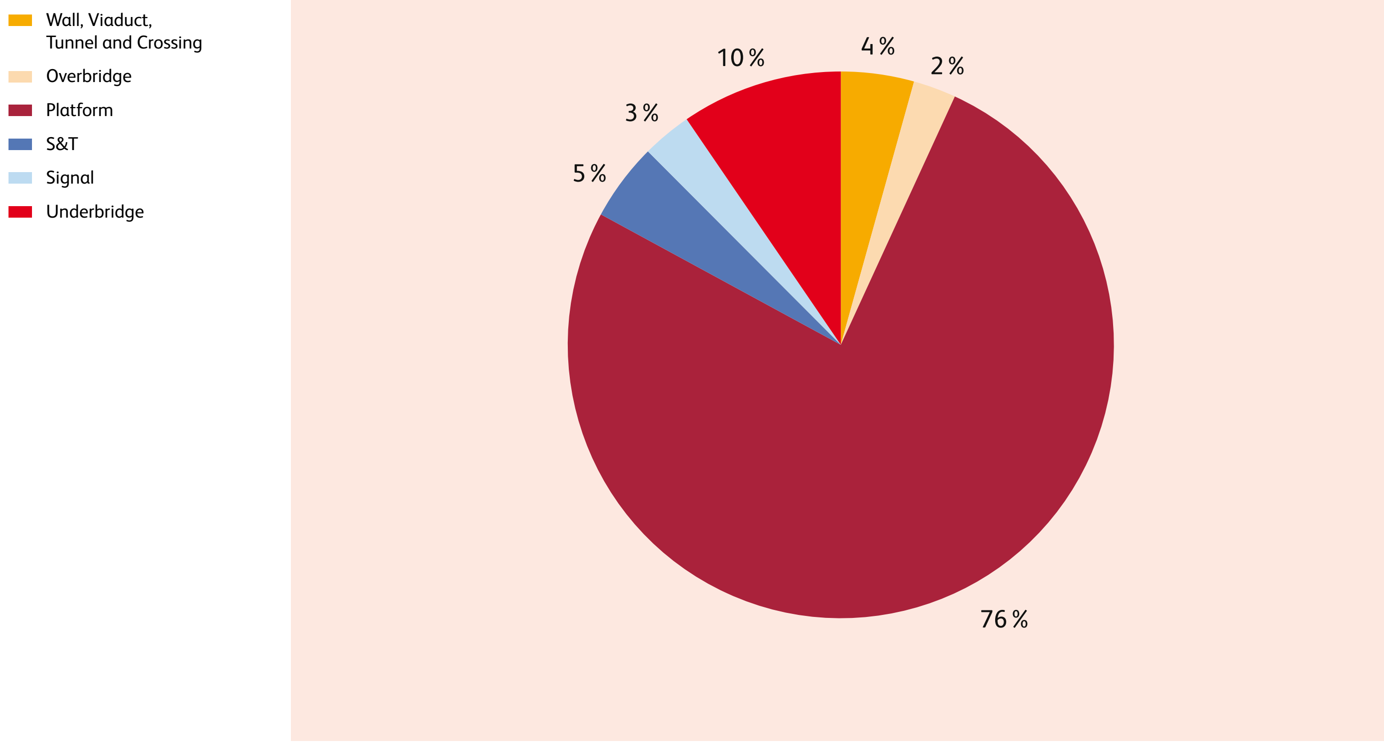
A series of vehicle profiles which currently operate on the network was considered to understand the implications for infrastructure gauge if a single kinematic envelope were to be used. The analysis showed that a high proportion of sub-standard clearances was related to platform vehicle clearances.

The analysis suggests that a gauge compatible with a 23 metre vehicle may be developed. If this were possible, there would potentially be fewer sub-standard gauging clearances.

The figures suggest that replacement of the 23 metre fleet with one or more generic 26 metre equivalents would barely cover the cost of the additional gauge clearance work. It is unlikely that a net saving would be achieved once the cost of platform extension work is included.

This development work would be required to focus on routes which are not used by the intercity market sector as these trains typically have a larger gauge than other types. Network Rail has conducted an initial analysis to begin this development process by testing the ability of the network to accommodate a series of existing outer-suburban, inter-urban and regional vehicles. This suggests that a number of the vehicles which are no more than 23 metres in length could be accommodated with a limited number of infrastructure interventions, of which the majority are relatively inexpensive platform modifications. **Figure 6.4** shows this breakdown, and **Section 6.7** discusses the likely cost implications of this.

Figure 6.4 – Sub-standard gauge clearances across the whole network with a variety of existing vehicle gauge profiles



Three sets of infrastructure capability changes are recommended to accommodate the new rolling stock, namely:

- gauge clearance of routes to accommodate the new trains that are built to the common specification for the market sector that these routes serve. This would include bespoke solutions to address individual instances where stepping distances are excessive
- platform lengthening on the routes where 20 metre vehicle trains are replaced with 23 metre vehicle trains. Replacement of 8, 9 and 10-car trains with 7, 8 and 9-car formations, respectively, would necessitate this at a number of stations
- continuation of the existing electrification programme to accommodate cascaded vehicles, subject to other industry planning processes.

These infrastructure capability changes would be required in advance of the delivery of replacement rolling stock.

Option 4.3 – Optimise vehicle length to reduce capital cost of a train

As discussed in the **Chapter 5**, the provision of equivalent on-train capacity through use of trains comprising longer, but fewer, vehicles may generate a cost saving, as the components that do not vary with the length of a vehicle are more expensive than those that do. Using fewer vehicles would equate to fewer bogies, wheel sets and vehicle inter-connections.

The basic reasons for lengthening vehicles are as follows:

- ***efficiency*** – to reduce the number of vehicles that need to be procured for the equivalent amount of capacity
- ***capacity*** – to maximise the use of available timetable capacity by having fewer longer vehicles per train.

The simplest way to achieve this would be upon life expiry to replace the 20 metre with a 23 metre vehicle train fleet.

Table 6.5 shows a matrix of train lengths which result from combinations of 20 and 23 metre vehicles. The colour coding highlights the closest match between a train length comprised of 20 metre vehicles when compared to a train comprised of 23 metre vehicles. It shows that an 8-car train comprised of 20 metre vehicles can be replaced by a 7-car train comprised of 23 metre vehicles for a change in overall length of only one metre. However, for formations of 20 metre vehicles greater than eight replaced by 23 metre vehicles, the train length increases. By contrast, formations of less than 8-cars long the overall train length reduces.

As a consequence, in order not to reduce capacity, it is either necessary to reduce the number of multiple units and therefore driving cabs or lengthen trains. While train lengthening may be a plausible solution to accommodate in some locations, infrastructure work would be required to accommodate longer trains across the network. Where fixed (or longer) formations are required there is likely be reduced operational flexibility.

Selective door opening – allows specific doors on a train to be selected open when required. This on-train feature allows the safe use of long train formations on services which may stop at stations with short platforms. It ensures that any coaches which are not aligned with the platform remain locked. However, it does mean that passengers which are situated in the rear of the train are required to move through the coaches to disembark. In order to alleviate passenger anxiety, trains with selective door opening (SDO) should have a means of informing the passengers of its use. There are advantages to using SDO, it can be an effective way of increasing train capacity whilst avoiding expensive infrastructure works, such as platform extensions, junction re-modelling and signal re-sighting. However, SDO is a compromise and may not always be an optimum solution at stations where there are very high volumes of passengers boarding and alighting.

If odd numbers of vehicles make up a train comprised of more than one multiple unit, then they must be formed of two lengths of units eg a 3-car and a 4-car forming a 7-car. In this scenario two sub-fleets would be required to operate a service. The alternative is a fixed 6-car formation thereby eliminating two driving cabs. However, the consequence of fixed 6-car formations will be to increase the minimum off-peak formation by three vehicles and thereby increase costs.

Currently 59 per cent of Diesel Multiple Units (DMUs) are 2-car units and 69 per cent of Electrical Multiple Units (EMUs) are 4-car units. These units when used in multiple, generally operate with other units to form an even number of vehicles per train. While there are some combinations in which two different length units are coupled together, in most instances all units are the same length when working in multiple, for example 4-car units may operate in the following combinations:

- 4-car
- 8-car (4+4)
- 12-car (4+4+4).

Vehicle lengthening is likely to result in either longer trains or longer fixed formation multiple units. The specific implication of these changes may be easy to accommodate if there is sufficient platform length on a route, or operational and market considerations mean that fixed or longer formations are appropriate.

Table 6.5 – Matrix of train lengths from comparable numbers of 20 or 23 metre vehicles

20 metre vehicles																						
1	20	23	20	46	20	69	20	92	20	115	20	138	20	161	20	184	20	207	20	230	20	253
2	40	23	40	46	40	69	40	92	40	115	40	138	40	161	40	184	40	207	40	230	40	253
3	60	23	60	46	60	69	60	92	60	115	60	138	60	161	60	184	60	207	60	230	60	253
4	80	23	80	46	80	69	80	92	80	115	80	138	80	161	80	184	80	207	80	230	80	253
5	100	23	100	46	100	69	100	92	100	115	100	138	100	161	100	184	100	207	100	230	100	253
6	120	23	120	46	120	69	120	92	120	115	120	138	120	161	120	184	120	207	120	230	120	253
7	140	23	140	46	140	69	140	92	140	115	140	138	140	161	140	184	140	207	140	230	140	253
8	160	23	160	46	160	69	160	92	160	115	160	138	160	161	160	184	160	207	160	230	160	253
9	180	23	180	46	180	69	180	92	180	115	180	138	180	161	180	184	180	207	180	230	180	253
10	200	23	200	46	200	69	200	92	200	115	200	138	200	161	200	184	200	207	200	230	200	253
11	220	23	220	46	220	69	220	92	220	115	220	138	220	161	220	184	220	207	220	230	220	253
12	240	23	240	46	240	69	240	92	240	115	240	138	240	161	240	184	240	207	240	230	240	253
		1		2		3		4		5		6		7		8		9		10		11
23 metre vehicles																						

No more than four metres difference	(green)
Between five and ten metres difference	(yellow)
Ten metres or more difference or significant capacity loss	(red)

However, more detailed analysis would be required on a route-by-route basis to establish the impact of longer vehicles.

Increasing the length of multiple unit formations, or moving to fixed formations increases the available seating and standing capacity for a given length of train because it eliminates space taken up with driving cabs at the end of multiple units. The Thameslink Rolling Stock Programme is specified to be in two fixed formation lengths, 8-car and 12-car. Currently on the Thameslink routes EMUs are 4-car units and may operate either singly as a 4-car, or an 8 or 12-car train. By contrast an 8-car fixed formation train eliminates two driving cabs, and a 12-car eliminates four driving cabs. This space then becomes available for passenger accommodation, thereby maximising the capacity for passengers of a 240 metre long train. Fixed formation trains by definition can only be operated in one length, so may provide significantly more capacity than is actually required in off-peak periods, and operating costs per mile are more expensive than in a situation where train length can be reduced in the off peak period by uncoupling and berthing parts of the train consist.

Strengths of fixed formations:

- maximises seating and standing capacity for a given length of train by removing driving cabs, making space available for passenger usage. This is relevant where all other means of maximising capacity have already been employed on a line of route. Where train frequency and train length have been taken to a practical maximum a fixed formation train allows the last elements of capacity to be obtained before more radical and costly solutions to obtain more capacity are required, such as double deck trains or indeed entirely new railway lines
- fixed formation vehicles can share auxiliary equipment across the whole train length and remove the need for duplication.

Weaknesses of fixed formations:

- fixed formations can only work as one length and therefore cannot be altered to match demand. A vehicle which needs to be removed from service for any reason renders a whole train out of service
- in the off-peak with a fixed formation capacity may be in excess of demand. This incurs increased operations, maintenance and variable track access costs without a commensurate level of passenger revenue
- depots and stabling facilities have to be full train length
- fixed formation fleets require fewer driving cabs to be produced, this means that:
  - multiple destinations cannot be served by splitting and joining
  - if a driving vehicle is defective the whole fixed formation must be withdrawn from service
- in the future if trains are reduced in length then the spare vehicles cannot easily be formed into additional trains as driving cabs may be in shorter supply than would be the case if the trains were designed to be worked in multiples
- only able to be split in a depot in limited combinations, for a 12-car it may only be possible to split into two 6-car sections to undergo maintenance because of the shared auxiliary equipment
- in extreme cases a driving cab damaged beyond repair might mean the whole train has to be withdrawn.

Fixed formation trains allow maximisation of capacity once all other conventional means of increasing capacity have been exhausted. However, this capacity may come at the cost of flexibility and the ability to match supply, in terms of train length, to passenger demand. Fixed or longer formations are therefore a toolkit option for consideration when increasing capacity.

Articulated trains

Articulated trains are fixed in their formation. However, instead of using the conventional dual bogie vehicle, each vehicle shares its bogies with the next vehicle in the formation. The use of articulated trains would allow an alternative optimisation of vehicle size, relative to the network gauge, because the gauging dynamics are different to those of a train made up of conventional vehicles. An articulated vehicle may need to be slightly shorter to negotiate similar gauging clearances but maximises vehicle width.

Advantages of articulation:

- fewer bogies, which brings significantly lower procurement and maintenance costs
- lower rolling resistance, leading to lower energy consumption and quieter noise emissions
- higher lateral inertia over bogies, which leads to reduced lateral dynamic displacement of bodies, bringing improvements in passenger ride quality
- potential for wider (albeit shorter) bodies (as in the Eurostar Class 373), leading to improved passenger capacity and/or comfort

- easier provision of full-bodywidth gangways, leading to better distribution of passengers and conditioned air throughout the unit, and better passenger security. This is a particular benefit for high density inner suburban services as this maximises standing spece
- easier sealing of gangways from external pressure pulses (eg entering tunnels)
- increase in passenger capacity
- increased space between bogies, with potential to transfer equipment from vehicle interior equipment cupboards to below floor level, leading to more space in vehicle interior for passengers
- potential to have higher proportion of wheelsets motored using fewer motors, leading to better power regeneration and braking, and lower procurement, energy and maintenance costs, with better adhesion and less wheel and rail damage during low-adhesion conditions.

Disadvantages of articulation

- higher average axle load (up to 17 tonnes), leading to potentially higher rail head wear, but may be ameliorated by having fewer axles
- depending on articulation system adopted, possible necessity for shorter carriage bodies, negating part of the savings from fewer bogies (but the use of shorter bodies gives potential for wider carriages and better relationship between doors and platforms)
- loss of flexibility as train formations are fixed

The use of articulated vehicles clearly can offer some advantages over a conventional vehicle, potentially offering a solution to increasing capacity and reducing maintenance costs. Nonetheless they may not offer the flexibility which some train operators require.

6.6 Options addressing legislative change

Options have been considered to address the legislative changes which bring change to the accessibility and environmental impact of rolling stock. **Table 6.6** which gaps each option addresses.

Table 6.6 – Options addressing legislative change

		Type A gaps – Rolling stock replacement				Type B gaps – Planning infrastructure and rolling stock together				Type C gaps – Operational flexibility of rolling stock			Type D gaps– Legislation	
		A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	D1	D2
5.1	Compliance with legislation – all new engines must not exceed target emissions													X
5.2	Use bio fuels to comply with the fuel quality directive													X
5.3	Rolling stock accessibility												X	

Option 5.1 – Compliance with legislation – all new engines must not exceed target emissions

All new engines fitted to non-road mobile machinery, which includes rolling stock, should be compliant with the Non-Road Mobile Machinery (Emission of Gaseous and Particulate Pollutants) Regulations 1999. This includes older rolling stock which is being fitted with a new engine. The implications of compliance may be challenging to accommodate the size of engines which comply with the legislation, increased fuel consumption and increased capital cost of the resulting diesel powered rolling stock.

Option 5.2 – Use bio fuels to comply with the fuel quality directive

The increased use of bio fuel is required in order to comply with the Fuel Quality Directive and minimise the harmful emissions from diesel powered vehicles.

Option 5.3 – Rolling stock accessibility

While the DfT is clear that an accessible rail fleet will be achieved by 1 January 2020, it recognises that there is little value in correcting minor non-compliances which do not materially reduce their accessibility to disabled passengers but can cost a significant amount to rectify. Instead, focus is being concentrated on those non-compliances which truly prevent disabled people from accessing rail vehicles. This 'targeted compliance' approach is being applied on a case-by-case basis in consultation with the rail industry and follows an assessment which identifies those areas, such as passenger information systems, where compliance by 2020 will be required.

6.7 Appraisal

This section presents a financial analysis of the options recommended in the previous section.

Appraisal assumptions

For clarity, options have been assessed against the base case described in **Section 6.1**, so the figures presented represent the likely saving in an area of the Rail Industry where costs are forecast to increase, rather than the cost saving against current levels.

The following financial impacts have been assessed:

- cost savings through more continuous procurement and economies of scale, resulting from replacement of rolling stock using the common train specifications
- cost savings through replacement of life-expired 8, 9 and 10-car trains comprising of 20 metre vehicles, with trains comprising 7, 8 and 9-car trains comprising of 23 metre vehicles
- the cost of gauge clearance work to accommodate rolling stock built to common train specifications.
- the cost of platform lengthening and associated work on the routes where 20 metre vehicles are replaced by 23 metre vehicles.

It is assumed that further electrification to accommodate a cascade of rolling stock would have a standalone business case, and the cost of this is not included in the analysis. Furthermore, the cost of alterations to platform stepping distances has not been included as it is understood that bespoke solutions could be identified in the limited number of instances where this is likely to occur, and for a cost of an order of magnitude lower than gauge clearance on platform lengthening.

Finally, this work has been conducted in accordance with DfT's WebTAG guidance, and all figures are presented in 2002 prices and values (prevent values) unless stated otherwise. An appraisal period of 70 years has been selected, which is longer than the

level typically used. The longer appraisal period has been selected in order to cover the full asset life and replacement of the existing rolling stock fleet using the high level characteristic of train types set out by this strategy in **Table 6.4.**

Appraisal results

Savings in the cost of rolling stock procurement and operation through more continuous production and economies of scale would build up over time as an increasing proportion of the fleet were based on the common train specifications. It is estimated that by 2021 around three per cent of the total annual cost of rolling stock would be saved, increasing to five by 2031 and 11 per cent by 2041. The total saving has an estimated present value of £3.6bn over the life of the appraisal period .

Similarly, the cost savings achieved by operating fewer, longer vehicles would also gradually occur over time, with the total annual cost of UK rolling stock forecast to reduce by one per cent by 2031 and also one per cent by 2041. The total saving has an estimated present value of £0.6bn over the life of the appraisal period.

Although the gauge clearance work would be required in advance of train replacement, it is not possible to estimate exactly when this is needed without the development work that would follow publication of the strategy. It has therefore been assumed that a programme of gauge clearance would begin at the end of Control Period 5, lasting a period of approximately 10 years.

Based on the train gauging data discussed previously a cost range has been estimated, with lower and upper bounds of £0.4bn and £1.5bn, and a central estimate of £0.7bn, excluding the cost of capital.

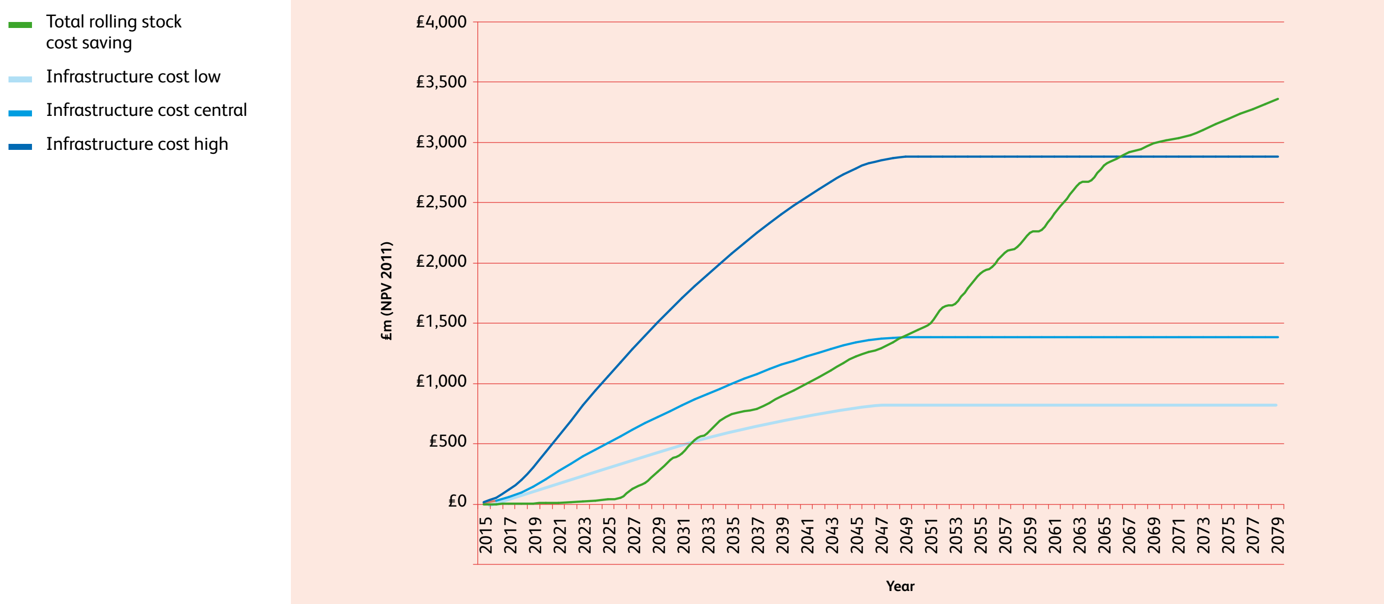
Similarly, it is not possible to forecast accurately when the platform lengthening work would be required, so the same profile as the gauge clearance activity has been assumed. The total cost of this platform lengthening is estimated at less than £100m.

Figure 6.5 illustrates the forecast annual rolling stock cost saving, minus the annual repayments on the range of infrastructure costs.

It is estimated that financial payback on the infrastructure work would be achieved between 17 and 52 years after commencement, with a central estimate of 32 years.

The total present value of rolling stock cost savings over the life of the appraisal period is estimated at £4.1bn, versus a total cost (including the cost of capital) of between £3.1bn and £0.5bn.

Figure 6.5 – Forecast annual rolling stock cost saving and capex cost



7. Consultation process and next steps

7.1 The consultation process

A Draft for Consultation of the Network RUS: Passenger Rolling Stock was produced in conjunction with the cross-industry Working Group and approved for publication by the Network RUS Stakeholder Management Group (SMG). It was published on 31 May 2011 along with a press release to announce its publication. A period of 60 days was provided to allow stakeholders and other interested parties to respond formally to its proposals.

7.2 The response to the consultation

61 responses to the consultation document were received. Those who responded broadly fell into nine categories. Formal responses were received from:

The RUS SMG and the RUS Working Group

- Association of Train Operating Companies
- Department for Transport
- London TravelWatch
- ORR
- Passenger Focus
- Passenger Transport Executive Group
- Rail Industry Association
- Transport for London
- Transport Scotland

Train Operating Companies and owning groups

- Arriva UK Trains Ltd
- East Coast
- First Great Western

Rolling Stock Companies

- Angel Trains

Passenger Transport Executives

- Centro
- South Yorkshire Passenger Transport Executive
- Strathclyde Partnership for Transport (SPT)
- Transport for Greater Manchester

Local authorities

- Birmingham City Council
- East Sussex County Council
- Essex County Council
- Exeter City Council
- Hampshire County Council
- Ipswich Borough Council
- Norfolk County Council
- Nottingham City Council
- Plymouth City Council
- South East Wales Transport Alliance
- Suffolk County Council
- Tandridge District Council
- Thurrock Council
- Warwickshire County Council
- West Norfolk Borough Council
- West Sussex County Council

Rail user groups and interest groups

- Association of Transport Co-ordinating Officers
- Campaign for Better Transport West Midlands
- Clydesdale Rail Action Group
- Fen Line Users Association
- Friends of the Far North Line
- Gatwick Airport Consultative Committee
- Great Eastern Mainline Vision Group
- HITRANS (Highlands and Islands Transport Partnerships in Scotland)
- Haslemere Rail Users' Group
- International Air Rail Organisation
- Leeds-Lancaster-Morecambe Community Rail Partnership
- Mid Cheshire Community Rail Partnership
- Railfuture
- Transform Scotland

Trade unions

- ASLEF

Other

- Cadia
- Elementus
- Gatwick Airport Ltd
- Institute of Mechanical Engineers – Railway Division
- ORR's Rail Industry Advisory Group
- The Chartered Institute of Logistics and Transport (UK)

We have received seven responses from rail users and people with an interest in the railway.

7.3 Key themes and issues in the consultation responses

7.3 1 Scope of response

The responses received were all well considered. Many of which gave full consideration to a wide range of issues raised in the consultation document and the proposed draft strategy.

Given the large number of comprehensive responses, it is impractical to provide an individual précis of each submission. However, copies of each of the organisations responses can be viewed at **www.networkrail.co.uk**.

The key themes and recurring issues have been summarised.

7.3.2 Key themes

There was widespread support for the proposals to reduce costs by planning rolling stock and infrastructure together.

Similarly there was a high level of support for the consolidation of train types serving the UK to bring simplification and enable economies of scale in procurement of new vehicles and make future cascade of vehicles much simpler.

There was broad support for the improved interfaces between rolling stock and the network and for the identification of cost inefficiencies in the procurement of rolling stock.

7.3.3 Specific issues

Rolling stock types

Many of the respondents have made supportive comments about the proposed move towards a more joined up approach when the industry procures new rolling stock. This was particularly because there are cost efficiencies to be gained.

A number of respondents emphasised the importance of competition in procurement of rolling stock. It was suggested that over specifying types and components of new build rolling stock could stifle innovation and potentially reduces competitive pricing. It was also suggested that the over specification may lead to monopolistic pricing structures.

Arriva observed in their response that suitable design of future rolling stock should be carried out by the suppliers and not the customers. Arriva considers that suppliers and not customers should design products, and procurement should be output based in order to avoid costly bespoke designs.

Three of the main suppliers of rolling stock to the UK market (Alstom, Bombardier and Siemens) have recommended that the future rolling stock types, which have been developed within this strategy, be considered as high level specifications to which they could respond with their product offerings.

In response to the comments raised by Arriva and the recommendation from the manufacturers, the strategy has clarified the definition of the proposed future rolling stock types and their application in future procurement initiatives.

Implementation of the strategy

A number of consultees observed that consideration needs to be given towards the implementation of the strategy and how the industry will work together to achieve the efficiencies identified.

Some consultees suggested that a market based approach to procurement would deliver the most cost effective procurement. ATOC and an individual TOC suggested that this could be most effectively achieved as part of the franchise process. The cost of procurement and the commercial risk of residual value are very strong drivers in avoiding costly and bespoke designs.

One of the ROSCO consultees considered the pros and cons of linking procurement dates arising from re-franchising. In recent years orders have been placed at the beginning of franchises. The respondent suggested that smoothing the procurement profile may be possible if franchise dates are staggered or if procurement is undertaken during the franchise.

Rolling stock procurement costs

There were a number of responses to the consultation which considered that the costs of new build vehicles highlighted in the draft strategy were not consistent with the current market prices. Angel Trains, Eversholt Rail Group and the Rail Industry Association (RIA) observed that the typical costs of rolling stock stated in the draft RUS were low and reflect costs seen before 2006. In response to this, the strategy has made reference to more recent evidence which highlights the increase in cost of new rolling stock. Consideration has also been taken that the costs can vary dependant upon the level of specificity defined by the customer.

ATOC and Arriva have also observed that the most competitive pricing of rolling stock will be achieved in a market-led procurement process where there are at least two potential suppliers. They suggest that competitive pricing will be stimulated by frequent procurement initiatives which are output based and not specification driven.

It has been observed by the manufacturers (Alstom, Bombardier and Siemens) and Arriva that quantity of procurement is not the only mechanism in achieving competitive unit prices. Large orders over a short periods of time increase unit costs because of the need to carry out parallel production methods and increase productive capacity. This is not inconsistent with the inclusion in the strategy of the recommendations to 'smooth' the procurement profile wherever it is efficient to do so. This observation has been addressed further within the strategy by collaboratively working with the main train manufacturers which supply the UK to understand the influence which productive capacity has upon unit costs. The strategy highlights evidence which was attained several manufacturers in a bilateral meeting hosted by RIA.

Several respondents suggested that while a long term procurement policy would bring the best value for money, it must maintain the commercial tension between suppliers.

Some responses inferred from the draft that the move to a limited number of train types would reduce the number of manufacturers in the market and create monopolies which could forego the potential cost saving. This was not the authors' intention and the text has been amended to reflect this.

Rolling stock life extension was considered by a number of respondents – it was suggested that it should neither be ruled in or out but allowed to be considered on merit of each case. It is essential that competitive tensions exist in the re-leasing and life extension market as it does in the new rolling stock supply market. In order to promote competition in re-lease and new build, plans should remain at a broad-brush indicative level. This has been clarified within the strategy as the draft document's intention was only in relation to the use of life extension as a means to smooth the future procurement.

Technical considerations

The Draft for Consultation implied that a means of improving vehicle compatability would be the development of a common interface between train management systems of different suppliers. Suppliers responded that this may be unrealistic as each system is the intellectual property of the supplier and any move towards aligning them would incur high development costs.

The adoption of relevant Technical Specifications for Interoperability (TSIs) is considered by the strategy. A number of respondents believed that further consideration of the progressive adoption of these standards, applied to both the infrastructure and rolling stock, represent a means to reducing industry costs and achieving further standardisation of the railway.

A train operator observed that freight operators use Class 66 locomotives which were successfully adapted from technology designed for the US market. It was suggested that passenger rolling stock manufacturers could explore the use of designs from overseas to save design costs.

A number of responses suggested that signalling and electrical power capacity interfaces should be considered when planning rolling and the network together.

Responses were received which suggested that Selective Door Opening (SDO) should be considered as a means to allowing longer trains to operate at stations with short platforms, whilst avoiding platform extension work at stations with low density passenger utilisation.

Technological advances have, in the past, been developed which make rolling stock more complex and incompatible with other rolling stock designs. A number of responses were received which highlighted the use of interface standards to ensure the interoperability of the UK fleet.

Rolling stock currently serving the market sectors

Individual consultees have highlighted that the passenger environment should be recognised as more than the interior of the train and that it includes all access routes and even extends to the provisions made to inform the passenger.

8. Strategy

8.1 Introduction

The Network Route Utilisation Strategy (RUS): Passenger Rolling Stock document has taken a long term view of future passenger rolling stock and the infrastructure it will operate over to establish whether there may be potential to plan the railway more efficiently. It follows a similar approach to other RUSs by considering the current situation, drivers of change, gaps and options to address the gaps. It has considered stakeholder aspirations, including those who fund, procure, operate and build the rolling stock.

Chapters 3 and **4** described the rolling stock currently operating on the GB rail network and key drivers of change which, when considered together, suggest that there could be significant potential for efficiency if a whole industry whole-life cost approach were to be adopted to planning the introduction of new rolling stock and infrastructure. The need to take advantage of potential efficiencies is made more urgent by an increasing requirement to replace ageing rolling stock and procuring new stock to accommodate growth.

Four groups of gaps were identified in **Chapter 5** based on a consideration of the effects of the drivers of change on the baseline. The gaps related to the requirement to replace existing rolling stock (Type A), the potential for planning infrastructure and rolling stock together (Type B), the potential for increasing operational efficiency (Type C) and those triggered by legislation (Type D).

Chapter 6 examines the requirements of each market sector and identifies options for future passenger rolling stock to meet its needs. The options include a consideration of whether there could be opportunities to exploit economies of scale through the procurement of fewer rolling stock variants.

The RUS then proceeds to examine the suggested rolling stock types alongside the network over which they may need to run. This is in order to assess the scale of any infrastructure works that may be required. It considers the advantages of planning the infrastructure consistently for the needs of each market sector. This includes the advantages of enabling rolling stock cascades, and 'go-anywhere-it's-needed' rolling stock for each market sector. It acknowledges that a market-based approach could yield savings.

This chapter outlines the resulting emerging strategy. It brings together the key strategic passenger rolling stock issues of concern to funders, Train Operating Companies and Network Rail, along with the railway industry's customers, suppliers and stakeholders.

Section 8.2 outlines the principles adopted in developing the strategy. This is followed in **Section 8.3** by a consideration of the rolling stock requirements of each market sector, identifying a number of common characteristics between each sector. **Section 8.4** discusses the infrastructure required to accommodate the rolling stock requirements and explores how a common kinematic envelope design might be useful for enabling rolling stock to be more inter-operable over the network. Finally **Section 8.5** discusses the phasing of the emerging strategy, including the interaction with major projects and franchising.

8.2 Developing the strategy

Passenger rolling stock costs are currently in the order of £1.8 billion per year, around 15 per cent of the annual costs of operating the railway as a whole. The strategy concentrates on the opportunities for efficiencies which arise from replacing existing rolling stock when it comes to the end of its commercial life and potentially procuring new rolling stock to meet the demand for growth. It addresses the advantages of standardisation of both trains and infrastructure and the need for a whole industry approach. It considers how planning the infrastructure and rolling stock together can enable the network to become more inter-operable to enable rolling stock which serves a particular market sector to go anywhere on the network it is required.

The overarching principle used to develop this strategy is to move towards a value for money whole industry whole life approach that delivers what passengers and funders require.

The key principles used to develop the emerging strategy are:

a) meet the needs of each market sector when ordering rolling stock

b) exploit the economies of scale in procurement whenever possible where this leads to long term efficiencies

c) consider those infrastructure works needed to allow rolling stock to be inter-operable within the market sector it serves

d) consider the phasing of future rolling stock procurement and infrastructure planning – in the light of re-franchising, major schemes etc.

The emerging strategy is purposely kept at a high level to identify the principles of what can be achieved. It avoids detailed specification of trains, other than to identify the key needs of each market. It highlights key economies of scale which may help reduce procurement costs and those physical characteristics of the trains and infrastructure which would enable rolling stock to be more inter-operable over the network. It is anticipated that train operating companies will be involved in the development of detailed specification of trains.

The strategy does not present a detailed plan for rolling stock procurement or life extension. This will need to be developed alongside changes in franchise policy and major infrastructure programmes over the coming years.

Similarly, whilst it identifies the infrastructure works that would be needed to deliver a more flexible inter-operable railway for each market sector, and presents the high level case (using unit costs) which suggests that there will be a value for money case, it does not cost every infrastructure intervention in detail. Local characteristics of each route will result in a wide range of costs in both gauge clearance and, where appropriate, platform length or height changes.

The network is currently operated by more than 12,100 passenger vehicles, which are members of 64 different rolling stock classes. There have been more than 5,000 new vehicles introduced since 1996, and substantial orders are being placed for new long distance high speed, Thameslink and Crossrail vehicles.

A large proportion of the fleet is considerably older. Historically the commercial asset life of rail vehicles has been considered to be 30 years for diesel units, and 35 years for electric units, although a number of vehicles have exceeded this. Recent technical research suggests that the life of some rolling stock can be extended considerably. Where life extensions meet customer expectations and are commercially attractive, immediate introduction of new build may not be the most effective solution. In theory, over the next ten years, over a quarter of the fleet would need to be replaced if its life were not extended beyond 30 or 35 years (for diesel and electric rolling stock respectively). Even if the life of much of the stock were to be extended by 5 to 10 years, less than 12 per cent of the fleet would still need to be replaced. In addition, if the rail industry is to accommodate the forecast growth in usage, it is likely to require a substantial number of additional vehicles in order to increase rather than simply maintain rolling stock capacity.

Given that the average cost of a vehicle in recent years has been between £1 million and £2 million, this potentially would involve considerable outlay at a time when the industry and its funders are striving to achieve better value for money solutions.

8.3 Rolling stock types by market sector

The RUS recommends that the industry and its funders consider the efficiencies which could result from procurement by reducing the variety of train types. In order to achieve this, it is recommended that consideration is given to the procurement of rolling stock which shares high level features with other rolling stock which serve the same market sector. Any reduction in the number of different types of vehicles procured may in turn lead to an increase in the size of order for each type of vehicle. This may reduce the unit costs of vehicles further.

Further efficiencies may be achievable by adapting designs for components from existing platforms, from the UK, Europe or elsewhere.

Whilst the reduction in the number of different train types which share a number of common features sounds an attractive proposition in theory, it only becomes attractive in practice if the train types match the needs of the market and can operate freely on all parts of the network where they are required. Passenger requirements were considered throughout the process and the RUS examines the requirements of the rolling stock in each market sector (as defined by the Department of Transport's 2007 Rail White Paper) at a high level. It suggests that, whilst there are understandable local variations in market needs, at the same time there will be common requirements that define the needs of each sector. The market sector requirements were then used to produce a very high level specification of a type of vehicle to meet the needs of each market.

This section takes the consideration of the requirements of each of the market sectors identified in the 2007 Rail White Paper as discussed in **Chapter 6** and combines them into five key types, that is

- **Type 1 and Type 2:** long distance high speed with a tilt variant
- **Type 3:** interurban and outer suburban
- **Type 4:** regional and rural
- **Type 5:** inner suburban

This strategy builds on the Network RUS: Electrification strategy which identified those areas of the network that were appropriate candidates for future electrification and, conversely, those which are unlikely to be future candidates. It is recommended that opportunities for efficiencies in rolling stock procurement or life extension are considered alongside opportunities for electrification to maximise the benefits.

Type 1 and Type 2 – Long distance high speed (LDHS) with tilt variant

The long distance high speed sector includes high speed services between large urban areas such as London and Leeds. It accounts for approximately 18 per cent of the total fleet. This sector is unique in its requirements and should be accommodated by types of vehicle which meet its particular requirements.

Its key requirement is a maximum operating speed of typically 125mph, ability to operate in long formations of up to 10 or 12-cars on the busiest routes, doors at the end of each carriage, with on-board facilities such as catering, toilets, luggage storage and staff accommodation.

Most long distance high speed services run on lines that are electrified or are recommended to be considered for electrification by the Network RUS: Electrification Strategy so it is recommended that the bulk of this fleet is comprised of vehicles capable of running under 25kV AC electrification. Given that future electrification is subject to affordability constraints, it is likely that there will be an on-going requirement for bi-mode vehicles (or a limited self-powered fleet) to run over sections of line which the Government does not plan to electrify in the foreseeable future.

The Department for Transport (DfT) is committed to the Intercity Express Programme (IEP), which will be the predominant train for the long distance high speed sector. On 1st March 2011, it confirmed a programme which will see the building of a combination of around 100 electric trains and bi-mode - diesel and electric – trains which will run on the Great Western Main Line and the East Coast Main Line.

The final specification of the train is to be determined by the DfT in negotiation with the supplier. The train operating companies will contribute to the design and specification of the new fleet.

Network Rail has been funded in its current Control Period to carry out initial works with a view to accommodating IEP vehicles which are expected to be 26 metres in length. Given the efficiencies which might be achieved by moving to fewer types of trains, the high level characteristics of the IEP, such as the vehicle length and width, could be the starting point for the long distance high speed family of trains, if these features prove to be the best value for money alternative.

In some instances the physical characteristics of the route may lend themselves to a different vehicle design. For example, on West Coast Main line, the use of tilt-enabled 125mph rolling stock is advantageous to achieve faster journey times.

Type 3 – Interurban and outer suburban

Type 3 specifies a vehicle which is suitable for the interurban and outer suburban market sectors where there could be considerable cost advantages if each of these market sectors were served with similar types of vehicle. The sectors have a number of common characteristics which may make it possible to serve them with as little as one generic type of train with the appropriate gauge and traction power. Whilst the basic construction might be similar, it is anticipated that details of the design, interior fittings and seat configuration might vary to meet the specific markets and operators.

The key requirements for rolling stock include a maximum operating speed of around 100mph (with some instances where 110mph or 125mph would be advantageous), and the ability to operate in both medium size formations (3 to 5-cars), and long formations (up to 12-cars) on busier routes. The flexibility of being able to operate in multiple units is helpful to meet lower levels of demand in the off-peak. The vehicles in this fleet would be 20 metre and 23 metre to give the flexibility to match supply and demand.

The Thameslink Programme currently underway will include the procurement of new units to operate the enhanced service structure. Whilst the final design of the vehicles has not yet been determined, a high-level specification has been published. The train will be of a metro-style, designed to accommodate large numbers of people over the approaches to London but also to provide a comfortable environment for passengers on longer journeys. They will allow rapid boarding and alighting of passengers. These trains will have a traction and braking profile that is in accordance with the operation of up to 24 trains per hour within the central core section of the route and have main line railway operating speeds up to 100mph.

The London Crossrail programme will also procure new vehicles. It is anticipated that these trains will be approximately 200 metres long and based on existing technology adapted to meet the service needs.

The basic technical characteristics of the Thameslink vehicle specification, such as weight, are in line with those identified in this strategy for the outer suburban railway. Economies of scale of procurement could be achieved if the Thameslink and other outer suburban rolling stock have a common kinematic envelope, allowing for market-focused interiors. Rolling stock in this sector is likely to require variants up to 12-cars. The demand characteristics would suggest that there might be a requirement for a 20 metre and 23 metre variant.

The fleet serving the interurban and outer suburban market sectors must be able to operate on both the electrified network (overhead and third-rail) and parts of the network which are recommended for future electrification by the Network RUS: Electrification Strategy. It is envisaged that variants of the vehicle would include 25kV AC electric, DC electric and dual voltage. Self powered vehicles may be required if a future business case for electrification on any of these routes does not warrant further investment in electrification infrastructure.

Type 4 – Regional and rural

Vehicles serving the regional market are often cascaded to serve rural routes. Given the earlier discussion on the economics of small orders, it is unlikely that the rural sector alone could economically be served by a bespoke vehicle. A common high level vehicle specification which is suitable for both the regional and rural market sectors represents an opportunity for future cost savings.

The regional and rural sectors have a number of common characteristics which may make it possible to serve them with one generic type of train with the appropriate gauge and traction power.

The key requirements for rolling stock include a maximum operating speed up to 100mph. Some rural services will require small formations, whilst regional service will require medium size formations (3 to 5-cars), and long formations (6 to 10-cars) on busier routes. The flexibility of being able to operate in multiple units is helpful to meet lower levels of demand in the off-peak. The vehicles in this fleet would be 20 metre and 23 metre to give the flexibility to match supply and demand.

Given that many of the routes in this sector are not recommended for future electrification in the Network RUS: Electrification strategy, it is anticipated that the vehicle type will have a self powered variant. It is envisaged that as the extent of the electrified network increases, the proportion of self powered vehicles within this fleet will decrease.

Type 5 – Inner suburban

The inner suburban sector describes the market for short distance commuting to, from and within major employment centres, for example the 'Great Northern Inners' service group to and from Moorgate. This sector accounts for 15 per cent of the total fleet. The inner suburban market has specific characteristics and it is envisaged that this would have its own vehicle type distinct from those operating in the other markets.

The key requirements of rolling stock serving this sector include fast acceleration and braking, door layouts that allow rapid boarding and alighting, and the ability to operate at a variety of lengths between two and 12-car formations. The rolling stock's absolute top speed may be lower for this sector, at up to 90mph.

As with all vehicles, the interiors of these vehicles would need to be specified by the TOCs according to the market need. It is anticipated that many of these vehicles would be configured with a high proportion of standing room to meet the heaviest demand approaching the city centres.

It is anticipated that the vehicle length for the inner suburban vehicles would predominantly be 20 metres. This is due to the constraints of infrastructure on which they operate. Consideration should be given to whether procurement of a 23 metre variant is required to meet demand. All inner suburban routes are either currently electrified or are on those routes which were recommended for consideration for electrification in the Network RUS: Electrification strategy. There will be a requirement for DC and AC dual voltage variants of the vehicle. As with other sectors, there may be a requirement for a self powered vehicle if a subsequent business case or affordability constraint meant that unelectrified lines remained so.

Summary

Table 8.1 shows the high level characteristics which have been identified for Types 1 to 5. Each of the vehicle types would share some basic high level characterstics and could account for a large portion of the total fleet. Each type would be expected to have variants of power or vehicle length. To achieve economies of scale in procurement, however, it may be appropriate for these to be produced to a common platform to avoid one-off start-up costs, balanced against the needs of avoiding monopolistic supply chains.

8.4 Infrastructure works required to allow inter-operability within a market sector

The RUS analysis has identified which lines on the network are used by trains serving each market sector. It is clearly a complex picture – with many lines being used by trains of more than one market sector (for example long distance high speed and outer suburban or inner suburban and outer suburban) and, indeed with freight.

If the economies of scale of moving towards a reduced number of rolling stock types are to be realised then it will be necessary for the chosen types to go virtually anywhere that its market sector needs it to go. For example, if there was only one high level specification of the basic dimensions of outer suburban rolling stock, it would be necessary for it to be capable of operating on all outer suburban routes.

Table 8.1 – High-level common vehicle specifications

Market sector vehicle type	Maximum speed (mph)	Acceleration	Traction power requirements	Vehicle length (m)	Minimum equipment level	Door layout
Type 1 – Long distance high speed	125 - 140	Standard	25kV AC electric Self powered Bi-mode	23 or 26	Very high	End
Type 2 – Long distance high speed (tilt variant)	125 - 140	Standard	25kV AC electric Self powered Bi-mode	23 or 26	Very high	End
Type 3 – Inter urban and Outer suburban	100 (occasional 125)	Standard	25kV AC electric Dual voltage Self powered	20 or 23	High	Market decision on door position
Type 4 – Regional and Rural	Up to100	Standard	25kV AC electric Dual voltage Self powered	20 or 23	Basic	Market decision on door position
Type 5 - Inner suburban	Up to 90	High	25kV AC electric Dual voltage Self powered Bi-mode	20 or 23	Basic	Market decision on door position

To achieve this, it is important that rolling stock and infrastructure are planned together. In particular, the gauge of structures, platform length, platform stepping distances, the ability of the network to accommodate different axle weights, and the total weight of potentially heavier longer vehicles need to be considered. Asset plans would need to consider the requirements of each vehicle type and, where multiple types operate, the prevalent requirements.

Figure 8.1 shows the network classified according to where the proposed three main vehicle types would be expected to operate. There are seven combinations; each shown in a different colour on the map. The combinations include a few routes where a single vehicle type operates but much of the network would be operated by two or more types.

Table 8.2 shows each combination in turn and expresses some of the high level considerations when planning the infrastructure.

Figure 8.1 – Future rolling stock types deployed over the network (indicative)

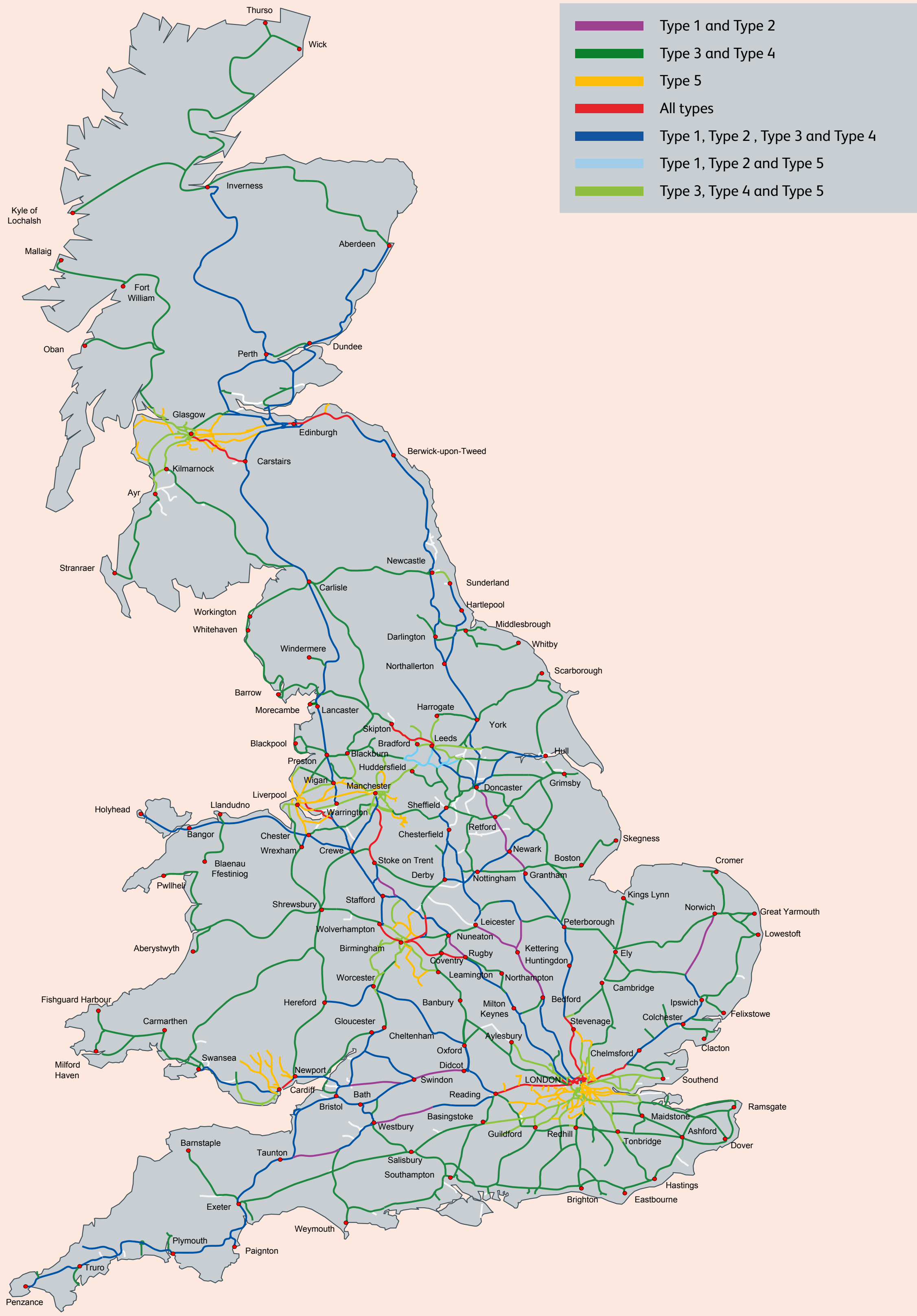


Table 8.2 – Infrastructure requirements for rolling stock types over routes

Infrastructure segment	Optimised for	Infrastructure requirements	Energy	Rolling stock characteristics
Type 1 & 2	Long distance high speed	Gauge to accommodate the longest vehicles. 23m or 26m for future IEP trains. Platforms lengths to accommodate the longest trains. Where trains pass through stations at high speed through stations, platforms must be of a sufficient width to ensure the safety of station users. Route availability for the longest and heaviest formations in the fleet. Signal spacing suitable for high speed vehicles. Gauge to allow for tilt trains on West Coast Main Line.	Electrified: – 25kV AC – regeneration capability Small proportion of non-electrified lines used for services.	High speed trains carrying a high volumes of seated passengers. Electric, self-powered and, if appropriate, bimode vehicles.
Type 3 & 4	Rolling stock serving regional, Interurban, outer suburban and rural market sectors	Gauge to accommodate vehicles of 20m and 23m. Platform length according to the service requirement, but generally range from 3 to 12-car in length.	Electrified: – 25kV AC – 750v DC – regeneration capability Some non-electrified lines used for services.	Mix of electric and self-powered rolling stock. Door arrangements are dependent on specific market sector.
Type 5	Rolling stock serving inner suburban market sector	Maximum availability. Track layouts for maximum capacity. Station layouts for high passenger throughput and minimum enhancement. Gauge to accommodate 20m and 23m vehicle lengths. Vehicles operating in London and South East areas may require to be 20m due to gauge restrictions. Platform lengths to accommodate vehicles between 2 and 12-cars.	Electrified: – 25kV AC – 750v DC – regeneration capability Small proportion of non-electrified lines used for services.	High density rolling stock catering for passengers travelling short distances in urban centres.
Type 1, 2, 3, & 4	Long distance high speed	Gauge to accommodate the longer, faster vehicles, 23m and 26m in length. Platform clearances need to be increased at stations where vehicles pass at high speed. Platforms will need to be able to accomodate variations in rolling stock length and door configurations.	Electrified: – 25kV AC – 750v DC – regeneration capability Some non-electrified lines used for services.	Combination of types 1 to 4

Table 8.2 – Infrastructure requirements for rolling stock types over routes

Infrastructure segment	Optimised for	Infrastructure requirements	Energy	Rolling stock characteristics
Type 1, 2 & 5	Long distance high speed	Gauge to accommodate the longer, faster vehicles, 23m and 26m in length. Platform clearances need to be increased at stations where vehicles pass at high speed. Platforms will need to be able to accomodate variations in rolling stock length and door configurations.	Electrified: – 25kV AC – 750V DC – regeneration capability Some non-electrified lines used for services.	Combination of types 1,2 and 5
Type 3 ,4 & 5	High passenger capacity	Platforms are required to accommodate a variety of train formations and vehicle types which may have different door configurations.	Electrified: – 25kV AC – 750V DC – regeneration capability Some non-electrified lines used for services.	Combination of types 3, 4 and 5
All types	Long distance high speed	Where all vehicle types need to be accommodated by the same infrastructure it will be necessary to build compromises in: Gauge to accommodate the widest and fastest vehicles. Platform lengths will need to accommodate the longer trains within the fleet. This will be driven by the service patterns and passenger loadings. Vehicle door positions may vary where differing train types are used.	Electrified: – 25kV AC – 750V DC – regeneration capability Some non-electrified lines used for services.	Combination of all types
Freight	Shared usage between freight and passenger rolling stock	Freight axle loading. Freight gauge capability requires consideration towards platform edge position. Signal spacing to account for long freight train formations.	Electrified: – 25kV AC – 750V DC – regeneration capability Non-electrified lines.	

Freight operates over much of the network. It will often be the determinant of the requirements for Route Availability (RA) and of the height and width elements of gauge. The Freight RUS and the Strategic Freight Network documents explain freight gauges in more detail and include maps of the routes which have been identified as candidates for gauge clearance for freight. Given that the optioneering in this strategy has dismissed double-deck trains and european gauge trains, fully laden intermodal freight trains will generally be the tallest vehicles operating on the network and will determine that element of gauge.

Gauge clearance, however, is determined by length of a vehicle as well as height and width. Length is rarely a factor for freight vehicles or their wagons but can affect the ability of passenger vehicles to operate on parts of the network.

The strategy recommends that further work is carried out to consider the high level requirements for passenger vehicles to meet each of the five train types discussed. This would enable them to operate at a gauge which would provide interoperability between routes. This approach would potentially facilitate cost savings and flexibility, whilst allowing operators to influence the detailed design of trains for the markets they serve.

Consequently, the strategy does not recommend specific rolling stock platforms or rigid train types which would meet the high level specifications for each sector. It is recommended that the rail industry develops a standard kinematic envelope from an understanding of the requirements of both rolling stock and infrastructure. This would enable a series of gauges to be built around the vehicle lengths identified for each train type.

The development of a standard kinematic envelope will give a rational basis for the future vehicle designs. The analysis undertaken in the strategy suggests that a single type of 23 metre rolling stock can be deployed across most of the network with relatively low costs for infrastructure interventions. This could be viewed as the starting point for routes which might require type 3 and type 4 trains (or any combination of trains where type 3 and type 4 was the largest train on the route). The desire is for a 'go anywhere' gauge. A deviation from this requirement may occur if there were structures which prove, upon investigation, not to be cost effective to clear. In such cases it might be more appropriate to procure a 20 metre variant of the vehicle. The development of the kinematic envelope should take cognisance of the dimensions of the Thameslink and Crossrail vehicles when they become available.

Similarly, the new IEP trains are being designed in parallel with the development of an understanding of the works needed to clear the gauge for vehicles of 26 metre long on key long distance high speed routes.

A higher degree of commonality in the characteristics of rolling stock and an associated joining up with infrastructure planning is consistent with the objectives of the European Commission in pursuing its interoperability initiative and a drive towards a common european market for railway assets, materials, components and processes. Increasingly, new rolling stock and infrastructure is specified together in Train Infrastructure Interface Specifications (TIIS).

8.5 Phasing of the strategy

In the course of the development of this strategy, manufacturers have pointed out that there would be potential savings if the procurement profile were to be smoother, that is, if similar size orders were placed regularly rather than the pattern of peaks and troughs which has occurred in recent years. As with any manufacturing process, costs can be avoided if the production line does not go through repeated patterns of stop/start. Our analysis suggests that up to 20 per cent of rolling stock procurement costs could have been saved between 1988 and 2010 if there had been greater continuity of orders. It is reasonable to suggest that considerable savings could be possible in the future if the future order profile offers greater continuity.

Discussions with the TOCs also suggest that the savings can be achieved through commercial negotiations, particularly in conjunction with the franchising process. Experience has suggested that there are advantages in maintaining competition between manufacturers and ordering smaller lot sizes with follow on orders.

In a commercial environment, there is inevitably a tension between manufacturers aspiration of continuity of orders and procurers aspirations to maintain competitive tension between suppliers, to reduce cost.

Whilst the savings from continuous production are potentially sizeable, the following factors are likely to preclude a perfectly smooth procurement profile:

- budgets in any financial year will be determined by affordability which is likely to vary year on year
- rolling stock procurement often occurs in conjunction with other events such as franchise procurement
- the need to phase rolling stock procurement with major infrastructure upgrades such as Thameslink, Crossrail and High Speed 2.

Indeed early replacement will shorten the period of life of the asset which may be reflected in its lease cost. Similarly life extension may lead to a requirement for complete overhaul of the vehicles or increased maintenance, also increasing costs. Nonetheless it is recommended that life extension is considered if it meets passenger requirements and enables tangible procurement benefits from achieving a smooth order profile.

Franchise reform presents opportunities for commercial decisions to be made around the life extension of existing vehicles or procurement of new vehicles. Refranchising represents a useful instrument for influencing the timing and pattern of orders.

It is recommended that the benefits of planning the infrastructure and rolling stock together and the economies of scale described are considered in procurement decisions, at an early stage in refranchising and in enhancement programme development.

The electrification program also presents opportunities for efficiencies as diesel rolling stock is replaced with new or life-extended electric rolling stock in key parts of the network.

The phasing of an infrastructure plan based on the requirement of each rolling stock type could then be developed in advance of the rolling stock's arrival on the network. The phased infrastructure plan would be presented to funders as part of Network Rail's Strategic Business Plan. As with all infrastructure plans this would be subject to the usual value for money appraisal and subject to affordability. The detailed requirements would accordingly be built into Network Rail's route asset plans and specifications.

Details of the train's specification, notably weight and lateral forces will be used to help calculate Network Rail's requirement for track renewal. Plans will also include understanding of power supply requirements and the interface with signalling equipment.

The gauging works required to accommodate the trains of each type should carried out at the same time as other gauging activities on the same route. As a guiding principle, a structure (bridge or tunnel) should be built only once. If the structure is on a route which needs to be gauge cleared for freight or electrification (as defined by the Strategic Freight Network or the Network RUS: Electrification strategy), it should be rebuilt only once, ensuring that it is consistent with all three strategies.

9. Next steps

9.1 Introduction

The Route Utilisation Strategy (RUS) becomes established 60 days after publication unless the Office of Rail Regulation (ORR) issues a notice of objection within this period.

The recommendations of a RUS – and the evidence of relationships and dependencies revealed in the work to meet them – form an input to strategic investment decisions made by the industry's funders.

9.2 Development work

Network Rail will seek funding to develop a set of kinematic envelopes to accommodate the high level specifications for rolling stock outlined in the strategy – specifically 23 metre and 20 metre train lengths.

Network Rail will seek funding to clear each of the routes identified in the strategy to the new gauges as the plan for introducing new rolling stock develops. This will establish the whole life costs and benefits of planning the rolling stock and infrastructure together on a specific route. It will develop an understanding of costs of all infrastructure elements which would be relevant to the introduction of the new trains, including the kinematic envelope, platform length (if appropriate) and platform stepping distances.

9.3 Progressive gauge clearance to the new kinematic envelope gauges

The strategy recommends that whenever a structure is renewed, it is cleared in accordance with the kinematic envelope required for each type of rolling stock expected to operate on the route. The overarching principle is that a structure should only be rebuilt once and that the gauge clearance will be consistent with the gauges specified by the Freight RUS and the Network RUS: Electrification strategy.

The new gauges will represent modern equivalent form which will be the starting point for renewal plans. This will facilitate a gradual clearance of the network, thus reducing the costs of subsequently introducing new rolling stock.

9.4 Asset Plans and Route Specifications

Network Rail asset plans will need to consider the requirements of each vehicle type. The infrastructure specification will be included in Network Rail's Route Specifications.

9.5 Review

Network Rail is obliged to maintain a RUS once it is established. This requires a review using the same principles and methods used to develop the RUS:

- when circumstances have changed
- when so directed by the ORR
- when (for whatever reason) the conclusions are no longer valid.

Appendices

Appendix A – Rolling stock fleet characteristics

Rolling stock characteristics: diesel mechanical and diesel hydraulic units						
Class Number	Class Name	Maximum speed (mph)	Number of carriages	Typical seating capacity of standard unit		Total weight of unit (tonnes)
				First Class	Standard Class	
121		70	1	0	65	38
142	Pacer	75	2	0	121	49.5
143	Pacer	75	2	0	92	48.5
144	Pacer	75	2	0	87	48.5
144	Pacer	75	3	0	145	72
150 / 0	Sprinter	75	3	0	240	99
150/1	Sprinter	75	2	0	148	76.4
150/1	Sprinter	75	3	0	224	114.7 114.5
150/2	Sprinter	75	2	0	149	74
153	Super Sprinter	75	1	0	72	41.2
155	Super Sprinter	75	2	0	160	77.6
156	Super Sprinter	75	2	0	150	76.5
158/0		90	2	0	138	77
158/0		90	3	0	208	115.5
158/8		90	2	13	114	77
158/9		90	2	0	142	77
159		90	3	24	170	115.5
165/0	Network Turbo	75	2	0	183	79.5
165/0	Network Turbo	75	3	0	289	116.5
165/1	Network Turbo	90	2	16	170	75
165/1	Network Turbo	90	3	16	270	112
166	Network Express Turbo	90	3	32	243	117.2
168/0	Clubman	100	4	0	278	171.5
168/1	Clubman	100	3	0	204	132.2
168/1	Clubman	100	4	0	278	175.7
168/2	Clubman	100	3	0	204	134.2
168/2	Clubman	100	4	0	280	178.9
170/1	Turbostar	100	2	24	97	89.8
170/1	Turbostar	100	3	45	119	132.8
170/2	Turbostar	100	2	9	110	91.4
170/2	Turbostar	100	3	7	173	133.7
170/3	Turbostar	100	2	18	96	91.6 - 93.1

170/3	Turbostar	100	3	7	162	137.5
170/3	Turbostar	100	3	7	162	137.5
170/4	Express (1)	100	3	18	172	132.9
170/4	Express (2)	100	3	18	172	137
170/4	Express (3)	100	3	0	198	136.1
170/4	Express (4)	100	3	0	188	133.8
170/5	Express (5)	100	2	0	122	91.7
170/6	Express (6)	100	3	0	196	134.1
171/7	Turbostar	100	2	9	107	92.5 - 95.4
171/8	Turbostar	100	4	18	167	180.4
172/0	Turbostar	75	2	0	124	83.1
172/1	Turbostar	75	2	0	124	83.1
172/2	Turbostar	100	2	0	124	83.1
172/3	Turbostar	100	3	0	193	121.3
175/0	Coradia 1000	100	2	0	118	101.4
175/1	Coradia 1000	100	3	0	186	148.9
180	Adelante	125	5	42	268	252.5
185	Desiro UK	100	4	15	154	163

Rolling stock characteristics: high speed diesel electric units

Class Number	Class Name	Maximum speed (mph)	Number of carriages	Typical seating capacity of standard unit		Total weight of unit (tonnes)
				First Class	Standard Class	
220	Voyager	125	4	26	160	185.6
221	Super Voyager	125	4	26	160	219.4
221	Super Voyager	125	5	26	220	276
222	Meridian	125	5	50	192	249
222	Meridian	125	7	106	304	337.8
222	Pioneer	125	4	33	148	202

Rolling stock characteristics: electric multiple units

Class Number	Class Name	Maximum speed (mph)	Number of carriages	Typical seating capacity of standard unit		Total weight of unit (tonnes)
				First Class	Standard Class	
313/0		75	3	0	231	104.5
313/1		75	3	0	231	104.5
313/2		75	3	0	196	TBC
314		70	3	0	218	102
315		75	4	0	244	127.5
317/1, 317/5		100	4	22	270	137
317/6		100	4	48	244	137
317/7		100	4	22	172	144.5
317/8		100	4	20	245	137

Appendix A

Rolling stock characteristics: electric multiple units						
Class Number	Class Name	Maximum speed (mph)	Number of carriages	Typical seating capacity of standard unit		Total weight of unit (tonnes)
				First Class	Standard Class	
318		90	3	0	212	110.5
319		100	4	0	319	136.5
319/2		100	4	18	221	136.5
319/3		100	4	0	300	140.3
319/4		100	4	12	274	136.5
320		75	3	0	227	114.5
321/3		100	4	16	292	140
321/4		100	4	28	271	140.4
321/9		100	4	0	293	138
322		100	4	0	291	138.7
323		90	3	0	284	114.7
332		100	4	26	148	179
332		100	5	26	204	214.8
333		100	4	0	343	186.4
334	Juniper	90	3	0	183	124.6
350, 350/2	Desiro UK	100	4	24	200	179.3
357/0	Electrostar	100	4	0	282	157.6
357/2	Electrostar	100	4	0	282	157.6
360/0	Desiro UK	100	4	16	256	168
360/2	Desiro UK	100	4	0	257	168.2
365	Networker Express	100	4	24	239	150.9
375/3	Electrostar	100	3	24	152	123.1
375/6	Electrostar	100	4	24	218	173.6
375/7	Electrostar	100	4	24	218	158.1
375/8	Electrostar	100	4	24	218	162.3
375/9	Electrostar	100	4	24	250	161.7
376	Electrostar	75	5	0	228	192.9
377/1	Electrostar	100	4	24	222	161.2
377/2	Electrostar	100	4	24	222	168.3
377/3	Electrostar	100	3	24	152	122.4
377/4	Electrostar	100	4	20	221	160.8
377/5	Electrostar	100	4	20	221	160.8
378/1	Capitalstar	75	4	-	146	160.3
378/2	Capitalstar	75	4	-	146	164.8
379	Electrostar	100	4	not yet available	not yet available	not yet available
380/0	Desiro UK	100	3	-	191	132.7
380/1	Desiro UK	100	4	-	265	167.5
390	Pendolino	125	9	145	294	460.7
395	Javelin	140	6	-	340	273.4

Rolling stock characteristics: 750V DC electric multiple units

Class Number	Class Name	Maximum speed (mph)	Number of carriages	Typical Seating Capacity of standard unit		Total Weight of unit (tonnes)
				First Class	Standard Class	
442	Wessex Electric	100	5	50	264	200.1
444	Desiro UK	100	5	35	299	221.8
450	Desiro UK	100	4	24	233	172.2
455/7		75	4	0	236	132.4
455/8		75	4	0	308	139.1
455/8		75	4	0	316	131.7
455/9		75	4	0	316	130.8 - 132.6
456		75	2	0	152	72.5
458	Juniper	100	4	24	239	169.5
460	Juniper	100	8	47	316	315.2
465/0	Networker	75	4	0	352	133.6
465/1	Networker	75	4	0	352	133.6
465/2	Networker	75	4	0	352	133.6
465/9	Networker	75	4	24	302	138.2
466	Networker	75	2	0	168	72
483		45	2	0	82	54.8
507		75	3	0	192	98
508/1		75	3	0	192-222	99
508/2		75	3	0	219	99
508/3		75	3	0	222	99

Rolling stock characteristics: loco hauled coaching stock

Class Number	Class Name	Maximum speed (mph)	Number of carriages	Typical Seating Capacity of standard unit		Total Weight of unit (tonnes)
				First Class	Standard Class	
MK3 (HST)		125	716	0 - 46	0 - 76	33 - 38
Mk 3		125	178	0 - 46	0 - 76	34 - 40
Mk 4		140	271	0 - 46	0 - 76	39 - 43

Rolling stock characteristics: night stock

Class Number	Class Name	Maximum speed (mph)	Number of carriages	Typical Seating Capacity of standard unit		Total Weight of unit (tonnes)
				First Class	Standard Class	
Mk 2 overnight seating		100	22	31		33.5
Mk 2 lounge car		100		26		33.5
Mk 3a sleeping car		100	61	12 or 13 berths		41- 43.5

Glossary

The following is a list of definitions for some of the terminology used in this document:

Term	*Meaning*
AC	Alternating current (electrical power supply)
ATOC	Association of Train Operating Companies
Axle load	The gross vehicle weight divided by the number of axles
Bogie	A supporting frame for wheel axles fitted beneath the end of a rail vehicle
Car	A coach or vehicle comprising part or all of a passenger train
CC	Competition Commission
CCTV	Closed Circuit Television
Coupling	The system allowing one or more vehicles to be attached to each other. There are a variety of types of couplers for passenger rolling stock
CP	Control Period (Network Rail five year funding period eg CP4 is from 2009-14)
DC	Direct current (electrical power supply)
DfT	Department for Transport
DMU	Diesel Multiple Unit
DOO	Driver Only Operation
DVT	Driver Van Trailer
EGIP	Edinburgh – Glasgow Improvement Programme
EMC	Electro Magnetic Compatibility
EMU	Electric Multiple Unit
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
Forecast	An estimate of patronage in a given future year
Franchise	Public Service Contracts for passenger rail services operated by Train Operating Companies for defined periods
Gauge	The physical clearance between vehicles and structure close to the track
GRIP	Guide to Railway Investment Projects
GSM-R	Global System for Mobile Communications-Railway
HLOS	High Level Output Statement
HS1	High Speed 1
HS2	High Speed 2
HST	High Speed Train
IIP	Initial Industry Plan
IEP	Intercity Express Programme
Kinematic Envelope	The characteristics of lateral and vertical movement of individual rolling stock vehicles in motion
LDHS	Long Distance High Speed
Locomotive Hauled Coaching Stock	Unpowered passenger rolling stock vehicles which are hauled by locomotives. These vehicles are distinct from multiple units (see below) where traction power is distributed throughout the train

LSSG	Lower Sector Structure Gauge
LSVG	Lower Sector Vehicle Gauge
Mk 1, 2, 3, 4	Mark 1, 2, 3, 4 types or passenger locomotive hauled coaching stock
MML	Midland Main Line
Multiple Unit	A train formed of two or more vehicles with traction power distributed throughout the train. Some multiple units can be coupled together with other multiple units to form a longer train at times of peak demand
NESA	National Electronic Sectional Appendix
NGD	National Gauging Database
Night Stock	Coaches used for sleeper trains
NRMM	Non-Road Mobile Machinery
ORR	Office of Rail Regulation
PRM TSI	Persons of Reduced Mobility Technical Specification for Interoperability
PTE/PTA	Passenger Transport Executive/Authority
PTEG	Passenger Transport Executive Group
RA	Route Availability
Regen	Regenerative braking
RFG	Rail Freight Group
RIA	Railway Industry Association
ROSCOs	Rolling Stock Companies
RSSB	Rail Safety and Standards Board
RTS	Railway Technical Strategy
RUS	Route Utilisation Strategy
RVAR	Rail Vehicle Accessibility Regulations
SDO	Selective door opening
SMA	Strathclyde Manning Agreement
SMG	Stakeholder Management Group
S&T	Signalling and Telecommunications
STPR	Scottish Transport Projects Review
Swept Envelope	The rail vehicle kinematic envelope (see opposite) also allowing for the effects of vertical and horizontal curvature of the track
TSIs	Technical Specifications for Interoperability
TIIS	Train Infrastructure Interface Specifications
TfL	Transport for London
TOC	Train Operating Company
Track cant	The slope of the track cross-section on a curve where the outside rail is higher than that of the inside
TSLG	Transport Strategy Leadership Group
UIC	Union Internationale des Chemin de fer (International Union of Railways)
VTISM	Vehicle Track Interaction Strategic Model
WAG	Welsh Assembly Government
WCML	West Coast Main Line