C4R

Capacity for Rail

Towards an affordable, resilient, innovative and high-capacity European Railway System for 2030/2050

Review of existing practice to improve capacity on the railway network

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EXECUTIVE SUMMARY

The European railway network has a total route length of around 212,000km, with an overall modal share of around 6% of passenger km and 10% of freight tonne km. The size of the network itself, following a decline in the 1990s, has remained relatively constant in recent years. There has however been a small decline in the number of freight vehicles. Despite growing in absolute terms (351bn passenger kilometres in 1995 to 407bn pkm in 2011), the railway network's modal share of passenger transportation has remained roughly static, and the share of freight transportation has decreased slightly against a backdrop of fairly constant absolute usage. Meanwhile, the competing national highway networks (much smaller at around 69000km) have continued to grow rapidly and currently carry almost half of freight tonne km and the overwhelming majority of passenger km.

The European Union has a stated ambition, driven partly by issues around the energy usage of transportation and associated climate change impacts, to make railways the primary mode of transport by enabling a significant increase in the modal share of this more environmentally friendly mode across passenger and freight transport in Europe. Various activities are underway at national and European levels to try to achieve this; for example, the Spanish Ministry of Public Works has published an infrastructure strategy referring to an ambition to more than double the modal share of freight traffic from 2010 to 2020. In recognition of the customers' requiring 'door to door' transport, the need to link the railways seamlessly with other modes of transportation is seen as critical to enabling the modal transfer. One complicating factor to achieving the ambitions, as this review has shown, is that although there has been a great deal of introspection across the industry and an associated development of road maps and strategies, it is still difficult to get a clear picture of the actual status of and the developments across European railways. This is mainly due to a lack of readily accessible documentation in the public domain.

The overarching needs of the 2050 railway system are recognised across the European countries to be: high capacity; low cost; reliability and seamless integration with the broader transport network. However, it is clear that to achieve this across Europe requires a holistic, whole-system approach, rather than the current segmented approach, e.g. route-level planning, which leaves lots of gaps. Operational misalignments, industry fragmentation and disconnect between planning and operations are significantly impacting on the available capacity on the network and the quality of service to customers.

The high-level objectives of Capacity4Rail are to support the achievement of the modal transfer for passengers and freight through the delivery of an affordable and reliable high-speed, high-capacity railway network with increased resilience, adaptability and automation. However, this has to be achieved in the context of tight budgets for public expenditure, rapid shifts in available technology, and the increasingly high expectations of customers; all this against competition from other modes of transport, especially the road network. Another level of complexity is added by the nature of the railway system itself; the aging and varied infrastructure across Europe, the relatively long life of railway vehicles compared to road vehicles that, for example slows the uptake of new technologies like automation.

Freight operators operate in a competitive environment, with other freight operators, passenger rail operators, as well as strong competition from road hauliers. The latter is particularly fierce, as shippers do not need to make any upfront investment to use road, and network access costs to road hauliers are not comparable to the access charges freight operators pay, both in terms of size and predictability. Rail freight also suffers from the disadvantages of not providing end-to end journeys, difficulty in competing for train paths with passenger trains and in general the lower levels of technology development (e.g. braking characteristics, noise, speed etc). The Rail industry is facing a number of additional challenges in terms of increasing the modal share of freight:

- Deployment of interoperable systems and infrastructure development;
- Ensuring adequate capacity in line with market needs and ensuring punctuality targets
- Promoting intermodality between rail and other transport modes by integrating terminals into the corridor management process
- Improving technology to enable the operation of mixed railways with the higher speed passenger railways.

The capability of the transport network to meet the growing demands being placed upon it is a growing concern. In addition to congestion on the road networks, crowding in public transport (road and rail) is becoming a serious issue. In the case of railways, the reality is that the demand, particularly in the passenger sector, is not evenly distributed on either a spatial or a temporal basis. Recent years have seen significant growth is some sectors, routes, times of day etc. For example, where commuters are the primary consumers, services have become extremely overcrowded during peak hours. There are numerous examples of excessive crowding on a number of routes. Crowding has effects on railway operations (e.g. operating speeds, dwell times, travel time reliability and modal choice) as well as the passengers (e.g. well-being and value of time) and it is therefore crucial to understand where, when and why railway capacity is needed.

At present detailed and accurate understanding of available capacity, usage and predicted growth in the different European countries is lacking. It is also clear that there is no single view on the key drivers of capacity constraints, and that the changes that would deliver capacity improvements are strongly influenced by the particular characteristics of a line/route. An improved understanding of current capability gaps is required to better match supply with demand and deliver a service that is valued by its customers. Analyses of the utilisation of the capacity being delivered by the system can help identify crucial bottlenecks.

These views also suggest that the capacity could be significantly improved by adopting technology solutions e.g. ETCS to reduce the amount of capacity lost to dated signalling practices. Additional technology improvements, more smart monitoring and increasing automation of operations could move usable capacity towards or even up to the theoretical maximum. As part of the Capacity4Rail study, one aspect would be to investigate increases in the level of automation in operations to deliver some of this potential increase in capacity.

Another key ambition for the transportation sector overall is the seamless, end-to-end journey, where customers are able to access the right mode of transport in the right place at the right time, optimising their use of the various modes available to them while minimising the cost and effort required. Again, although this is being addressed, the effort is piecemeal. The development of tools for journey planning, across both freight and passenger traffic, is a major area of innovation, and some modal interchanges are being optimised (e.g. synchronising timings between buses and trains), but these activities are happening in separate silos.

The transportation system is vulnerable to extreme weather events like heat waves, high winds and heavy precipitation, which can result in significant direct costs to the IMs, operational costs to the RUs and customers through disruption and, if not well-handled, reputational damage to the service providers. However, these events are not evenly spread, and what is considered an extreme event in one location is business as usual in another. Although the experience to meet the challenges of 'extreme' is out there, there appears to be limited knowledge transfer and sharing of experience. Applicability of external experience is also constrained by national standards, priorities, perceptions etc. Greater efforts are beginning to be expended on helping to share good practices across Europe, and ensuring that appropriate lessons are learned and shared from each experience but structured, collated information on causes, costs and impacts is not currently available. Strategies for dealing with sudden unexpected temporary variations in demand are still in the early stages of development on both railways and highways.

TABLE OF CONTENT

ABBREVIATIONS AND ACRONYMS

Abbreviation / Acronym	Description
AB	Allocation Body
CUI	Capacity Utilisation Index
DfT	Department for Transport
EIM	European Rail IMs
HA	Highways Agency
IM	Infrastructure Manager
PiXC	Passenger in Excess of Capacity
pkm	Passenger kilometres
RNE	RailNetEurope
RU	Railway Undertaking
SPAD	Signal passed at danger
TEN-T	Trans-European Transport Networks
TOC	Train Operating Company (GB term for RU)
TSI	Technical Specification for Interoperability
Variable Message Sign	VMS

1 BACKGROUND AND OBJECTIVES

Task 3.1.1 of the Capacity4Rail project aims to "understand current practices to improve capacity across Europe" and to "identify the interim steps to achieve the future adaptable, resilient, automated transport network".

This deliverable is related to the work in Task 5.1.1, which aims to "draw the current situation in infrastructure/freight/operation/health monitoring and identify future requirements, technologies and visions for improvements". It was intended that this report would build on the deliverables of Task 5.3.1, which aims "to develop and verify steps to migrate from the existing system to the future one" (D5.3.1 and D5.3.2, both yet to be delivered).

Per the Description of Work, this deliverable reviews:

- The opportunities and limitations of current networks, e.g. how much capacity is available and how much of it can be accessed;
- Planning methodologies and strategies currently in use (rail and other transport modes) – how are capacity constraints identified and assessed, and how are appropriate solutions developed and selected;
- Targets, objectives and scenarios (e.g. types of network – conventional and TEN-T networks, high speed passenger and freight) for capacity improvement and the timescales over which they are considered;
- Strategies currently in place for dealing with unforeseen temporary variations in demand and available capacity , either at link or network level; and
- Methods used to address interactions with other transport modes for the benefit of passengers (e.g. enabling seamless end-to-end journeys) and freight (e.g. transhipment at multi-modal hubs and nodes).

Chapters 2 to 6 align with these bullet points.

2 OPPORTUNITIES AND LIMITATIONS OF CURRENT NETWORKS

2.1 NETWORK SIZE

The overall size of the European railway network (length of lines in use across the EU-27 countries) has remained more or less unchanged in recent years, having declined in the 1990s. By contrast, the road network has continued to grow; Figure 1 [1] compares the growth of motorway (roads with grade-separated junctions) and railway networks across Europe from 1990-2010. Although the railway network is much larger (212,789 route km in 2010, vs. 69,468 route km) the motorway network is growing rapidly.

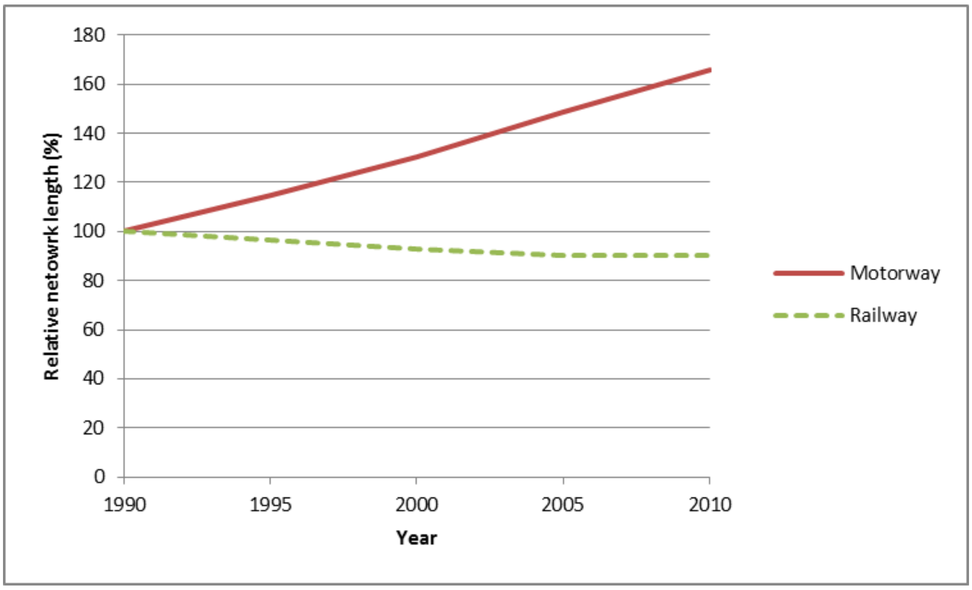


Figure 1: Comparison of motorway and railway network growth, EU-27 (1990=100)

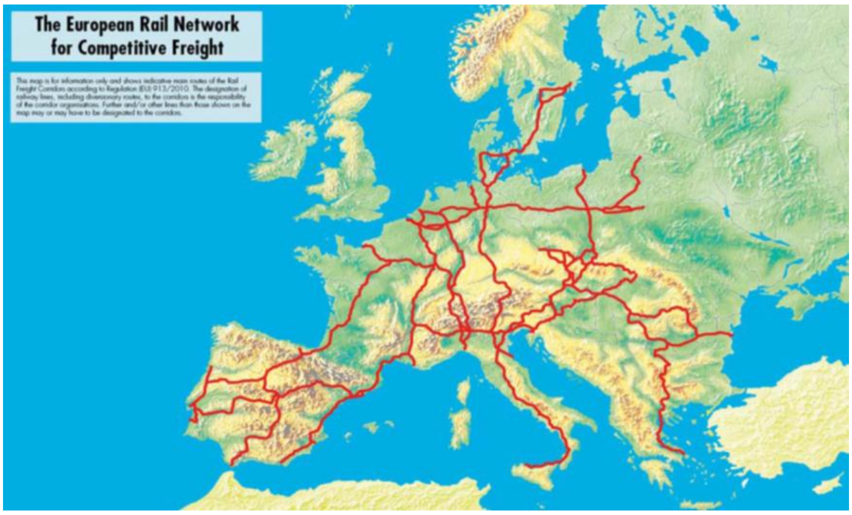


Figure 2: European Rail Network for Competitive Freight

Figure 2 [2] shows the rail freight corridors in Europe; this indicative map demonstrates the extent of the network for the competitive and efficient movement of freight around Europe.

2.2 ROLLING STOCK QUANTITY

Another measure of capacity is the rolling stock available to run services. Figure 3 [1] shows the relative numbers of passenger vehicles (coaches, railcars and trailers) and goods wagons from 2000-2010. Although rail passenger vehicle numbers show a slight overall increase over that period, there has been a significant decline in the number of freight vehicles.

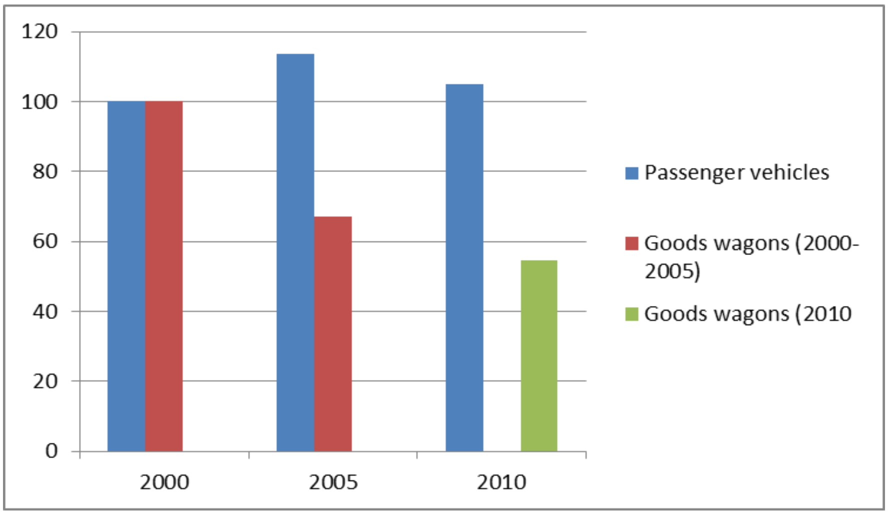


Figure 3: Comparison of passenger and goods vehicle numbers, EU-12 (2000=100)[1]

[1] 2010 data for goods vehicles does not include private-owners' vehicles, hence is shown in a different colour

2.3 MODAL SHARE

Figure 4 and Figure 5 [1] show the modal share for passenger and freight transport, respectively. Note that passenger car usage has not been shown in Figure 4 as it is significantly larger than the other series.

In passenger transport terms, although the absolute usage of the railway has increased from 351bn passenger kilometres (pkm) in 1995 to 407bn pkm in 2011, the modal share remained around 6% over the same period. At around 73%, the passenger car has remained the primary mode of passenger transport, with total road share down only slightly (from 85% in 1995 to 83% in 2011).

For freight transport, railway's share has declined slightly, with a fairly static absolute usage of 410bn tonne km in 1997 and 420bn tonne km in 2011. Again, road is the primary mode, with sea transportation holding a steady second place.

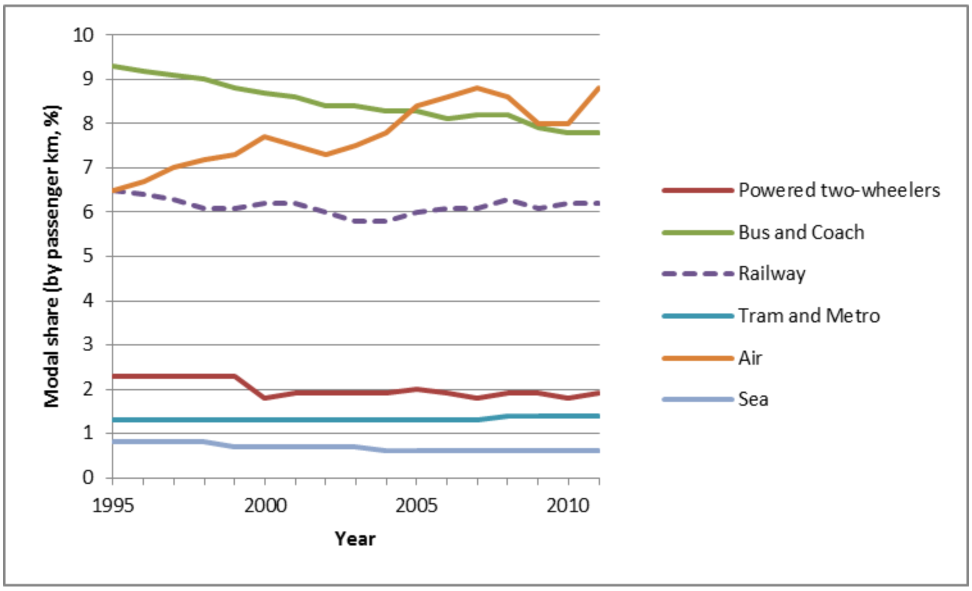


Figure 4: Modal share of passenger transport, EU-27 (passenger car not shown)

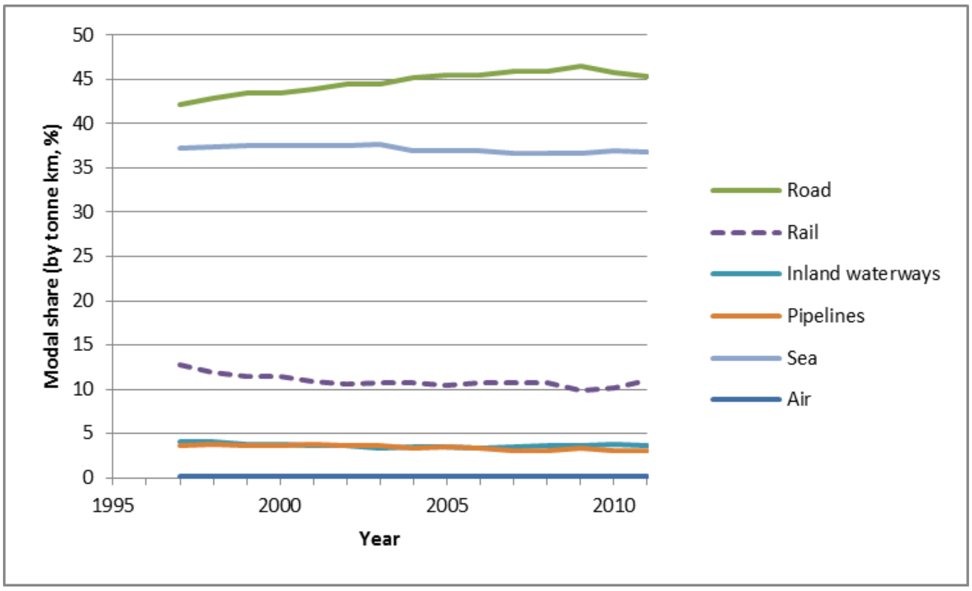


Figure 5: Modal share of freight transport, EU-27

However, rail and transportation strategies in several European countries refer to aims to increase the capacity and modal share of rail, particularly in terms of reducing the environmental impact of transportation. For example:

- The Spanish Ministry of Public Works' Infrastructure Strategy includes an aim to increase the market share of rail freight traffic – a specific strategic plan for promotion of rail freight aims for an increase in modal share to 8-10% by 2020, compared to 4.1% in 2010;
- Austria's ÖBB has ambitions to increase passenger train km by 30% and freight volume by 40%, by 2025 ("Zielnetz 2025+"); and
- The European Commission's Transport White Paper called for a substantial expansion in modal share for passenger and freight over medium and long distances (EC, 2011).

2.4 Capacity utilisation

The usage of the railway network has increased significantly in recent years; in the UK, for example, the number of rail passenger journeys has more than doubled in the period from 1995-2013 [3]. Figure 6 shows a comparison of freight moved and passenger journeys on the GB rail network; passenger numbers have been growing steadily and freight movements have returned to growth after dropping between 2005 and 2010.

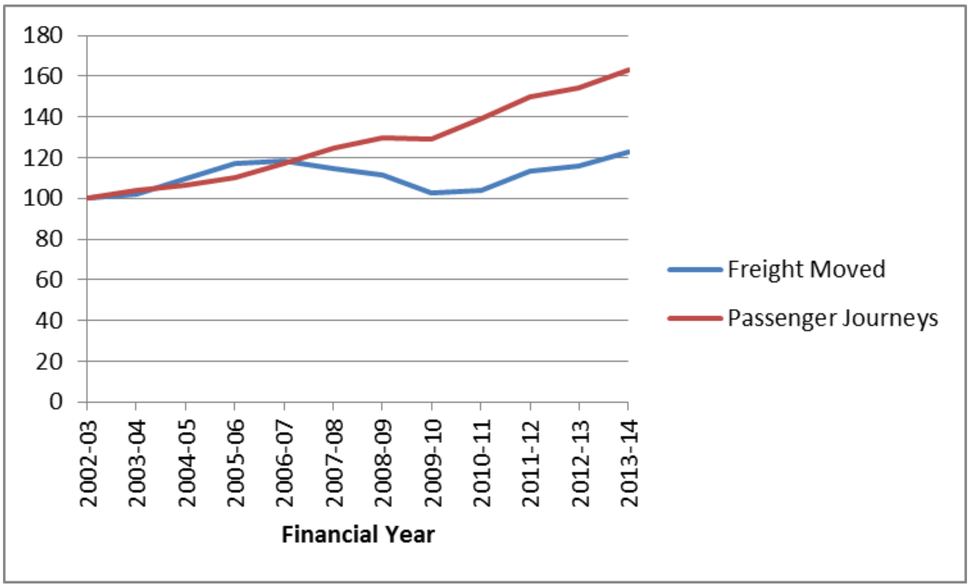


Figure 6: Comparison of GB railway freight and passenger usage (2002-03=100)

Taking a longer-term view, Figure 7 shows how passenger rail transportation usage in Sweden (measured in billion passenger kilometres per year) aligns with developments inside and outside the railway system. For example, the reduction in long distance (>100km) rail journeys aligned with the expansion phase of air travel between 1980 and 1990.

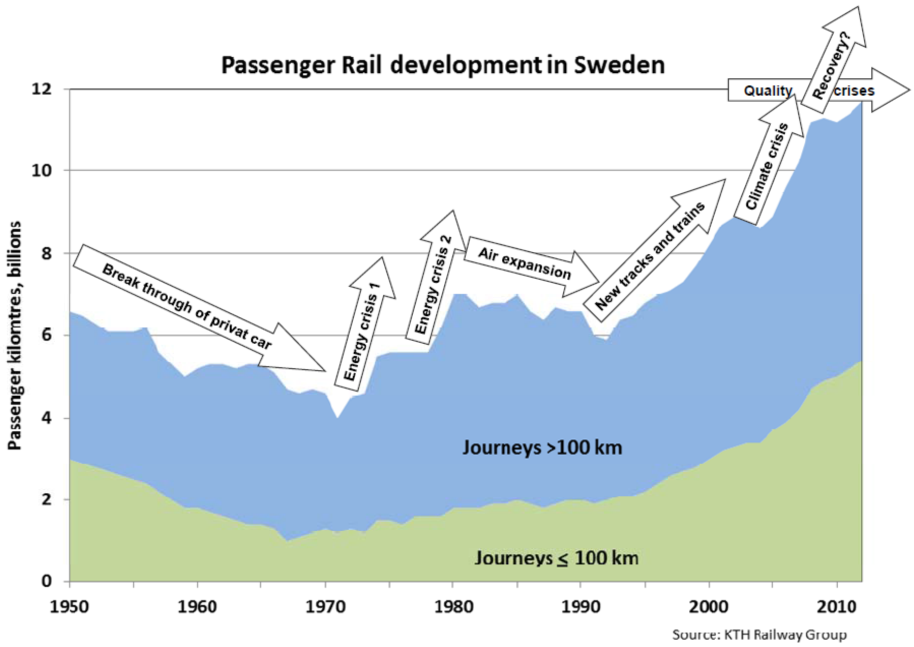


Figure 7: Development of rail passenger transportation in Sweden, 1950-2013

2.4.1 PASSENGER CROWDING

Crowding in public transport (road and rail) is becoming a growing concern as demand is continuing its growth trajectory and is increasingly being used as a measure to represent capacity [4]. Standing passenger density is used by many rail industries around the world as a common measure for crowding [5]. Crowding has effects on railway operations (e.g. operating speeds, dwell times, travel time reliability and modal choice) as well as on the passengers (e.g. well-being and value of time) [6].

In contrast to freight transportation, where it is optimal to fill each wagon to its maximum capacity, crowding is a major customer service issue for passenger transport. For example, train operating company (TOC) franchise contracts in the UK include an obligation to avoid "excessive" overcrowding. The metric used to measure passenger crowding in the UK is Passengers in Excess of Capacity (PiXC), defined as:

"the number of standard class passengers on a service that are in excess of the standard class capacity at the critical load point. It is the difference between the standard class passenger load at the critical load point and the standard class capacity, or zero if the passenger load is within the capacity. Capacities include the number of standard class seats, and also include a standing allowance if the time between stations at the critical load point is 20 minutes or less."

In autumn 2012 approximately 20% of passengers of passengers arriving in London during the morning peak had to stand at trains' busiest points [7]. Even a gross hourly analysis of passenger numbers and seats (as shown in Figure 4) shows the former exceeding the latter during the morning peak.

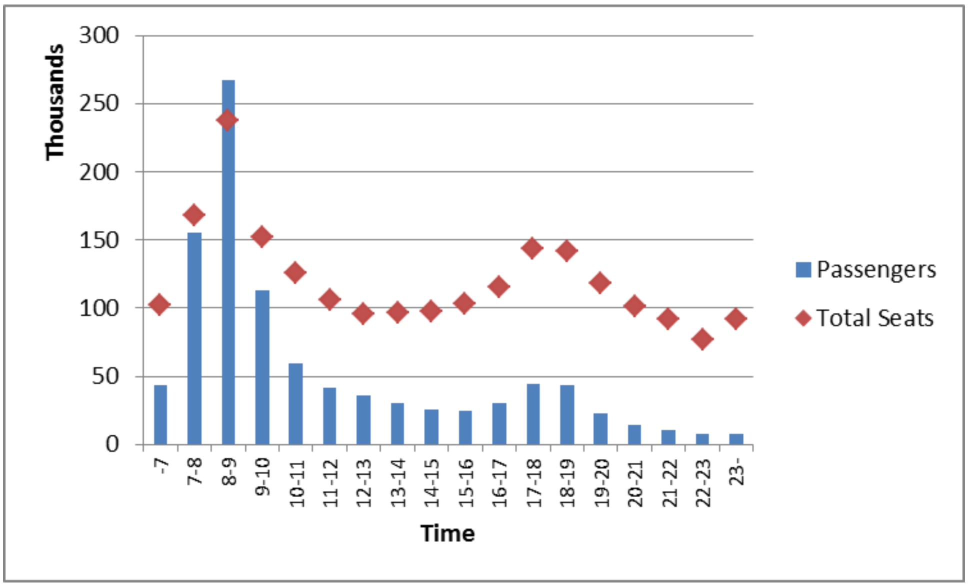


Figure 8: Comparison of passengers arriving in London with available seats (typical autumn weekday, 2012)

These figures also show the significant excess capacity into London available throughout the majority of the day. As the accompanying notes put it:

"As these are aggregate figures they hide a lot of detail, as there will be crowding on some routes and services while others have spare capacity. However, they do demonstrate how outside the peaks there is often a large amount of spare capacity, although this spare capacity will generally not be transferrable between routes or to other times of day."

For example, the UK Wessex Route Study [8] quotes the current capacity into London Waterloo during the peak hour (arrivals between 8.00 and 8.59) as 17,600, compared to passenger numbers in excess of 19,000. Table 1 [9] lists the 10 most overcrowded peak train services in major cities in England and Wales, which all exceed available capacity by upwards of 50%.

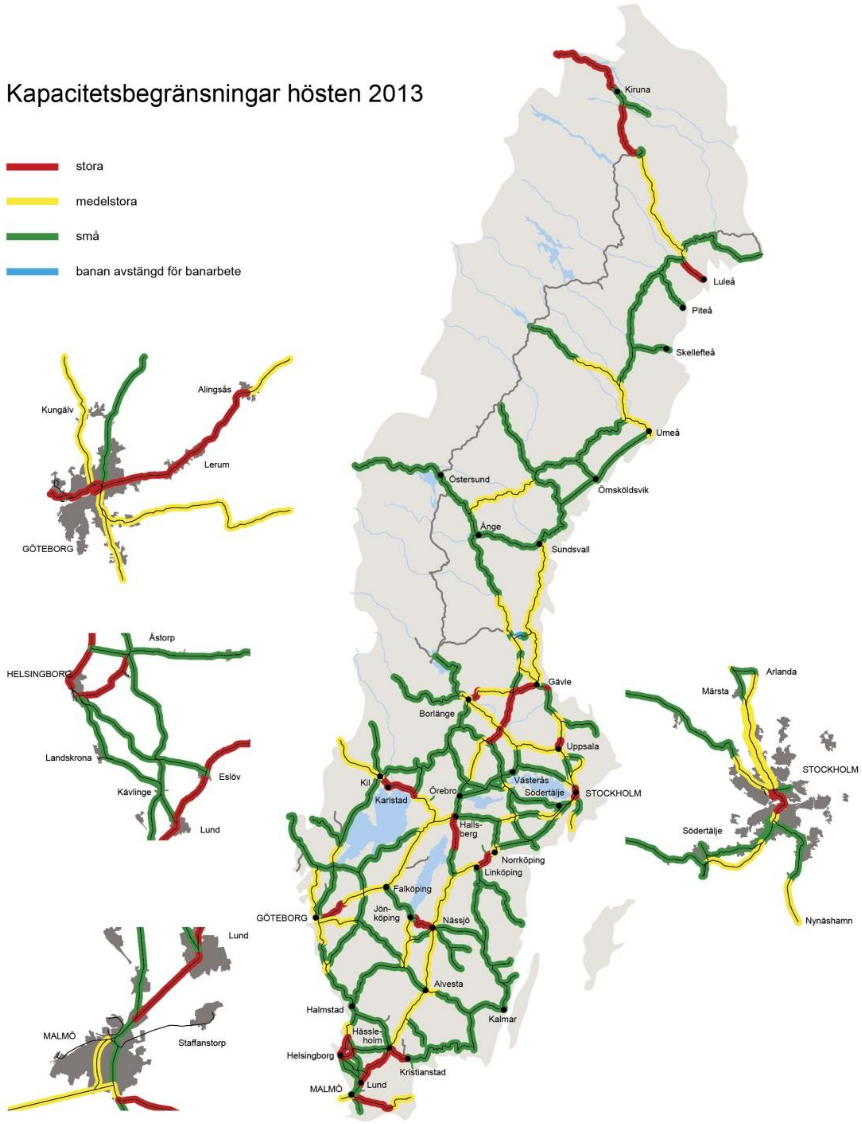
Table 1: 10 most overcrowded peak train services in England and Wales, Autumn 2013

	TOC	Departure Time	Origin	Destination	Standard Class Load Factor (%)
	London Midland	16.46	London Euston	Crewe	211
	South West Trains	07.32	Woking	London Waterloo	173
	First Great Western	07.21	Oxford	London Paddington	173
	Heathrow Connect	18.33	London Paddington	Heathrow Airport	169

	TOC	Departure Time	Origin	Destination	Standard Class Load Factor (%)
	TransPennine Express	06.30	Manchester Airport	Middlesbrough	166
	London Midland	18.13	London Euston	Birmingham New Street	164
	First Great Western	06.07	Banbury	London Paddington	157
	TransPennine Express	06.30	Scarborough	Manchester Airport	156
	East Midlands Trains	06.28	Nottingham	St Pancras	155
	First Great Western	07.00	Oxford	London Paddington	153

2.4.2 UIC 406

A common measure of capacity utilisation is the methodology outlined in UIC's Leaflet 406. For example, Trafikverket produced the map shown in Figure 9 using the UIC 406 method



[10].

1.1.1 Capacity Utilisation Index

In the UK, the Capacity Utilisation Index (CUI) is used as an indicative measure of how much of the planning capacity of a section of railway is being used by the current timetable. Figure 10 [11] shows the peak CUI map for the GB rail network.

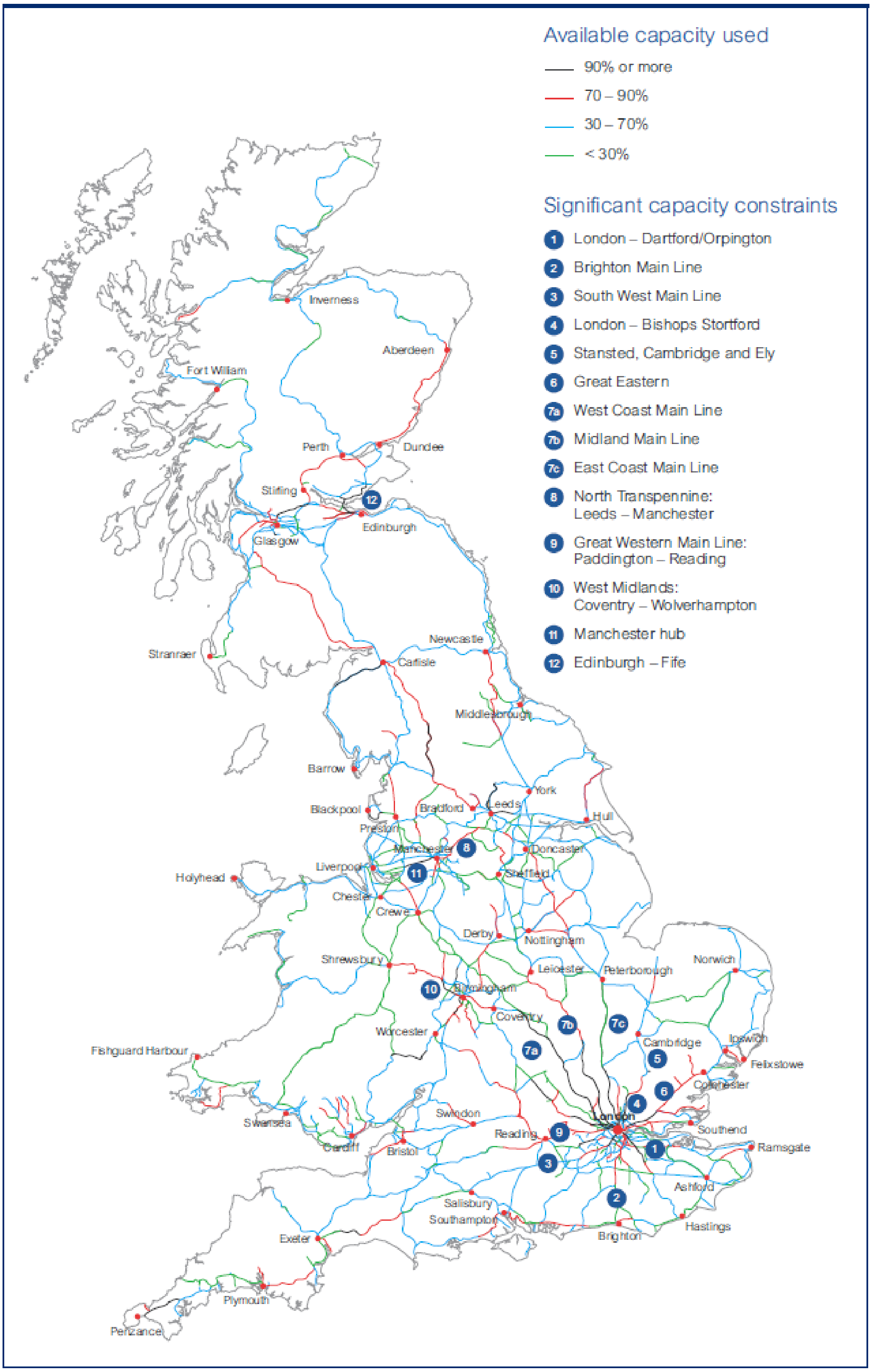


Figure 10: Network Rail peak CUI map

In 2010, TRL and the University of Birmingham organised a stakeholder workshop as part of a DfT-sponsored research project to review railway capacity in the UK and elsewhere [12]. One idea used during the workshop was that of the "network diagram", demonstrating: the overall capacity available; where capacity is lost; the factors that contribute to this loss; and the associated proportions of the lost capacity. Following the workshop, several stakeholders submitted their own capacity breakdowns, giving their views on how capacity is being lost on the network. These are shown, in no particular order, in Figure 11

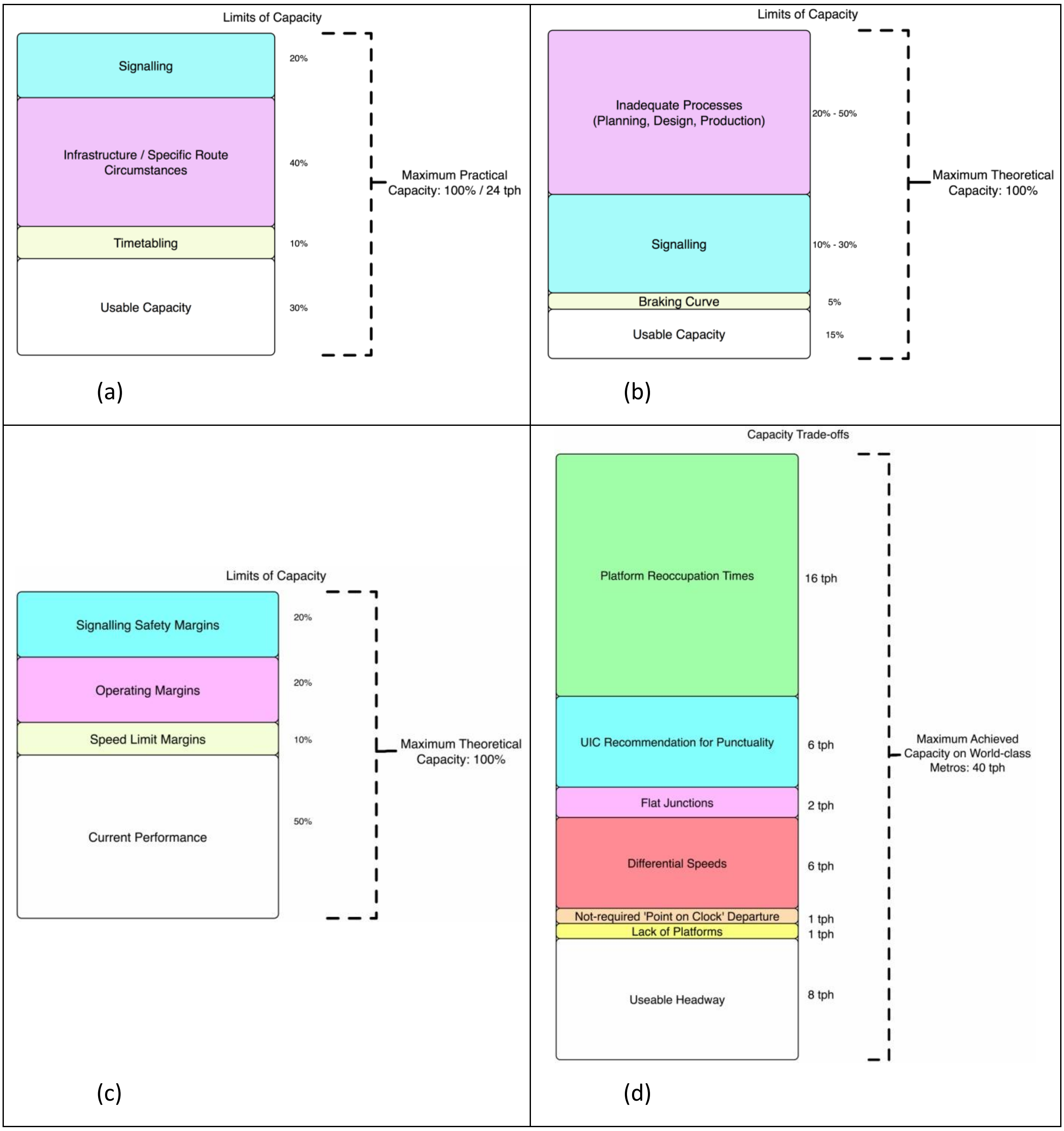


Figure 11: Railway network capacity diagrams

It is clear that there is no single view on the key drivers of capacity constraints, and that the changes that would deliver capacity improvements are strongly influenced by the particular characteristics of a line/route. These views also suggest that the capacity could be significantly improved by, for example, adopting ETCS to reduce the amount of capacity lost to current signalling practices. Additional technology improvements, such as improving braking rates and adhesion control and increasing automation of operations could move usable capacity towards or even up to the theoretical maximum. As part of the Capacity4Rail study, one aspect would be to investigate increases in the level of automation in operations to deliver some of this potential increase in capacity.

2.5 Capability gaps – a potential approach for C4R

When attempting upgrades to improve the capacity of railway lines, it is common practice to start from existing technologies and incrementally add improvements to the line until it achieves the required capability. In general, schemes to improve capacity tend to include infrastructure options such as improvements, alterations and additions to track layouts, grade separation of junctions, extensions to platforms, etc. These can turn out to be sub-optimal, high-cost solutions if the other parts of the railway system are not considered.

A whole-systems approach provides a structured and systematic way to identify appropriate and more affordable solutions to improve capacity. The fundamental premise of systems engineering and capability engineering is to:

- Set the anticipated future operating scenarios;
- Establish capability gaps and functional requirements; and
- Select technologies (and potential specifications).

A whole-system process that could be used in Capacity4Rail to identify options for capacity improvement is shown in Figure 12.

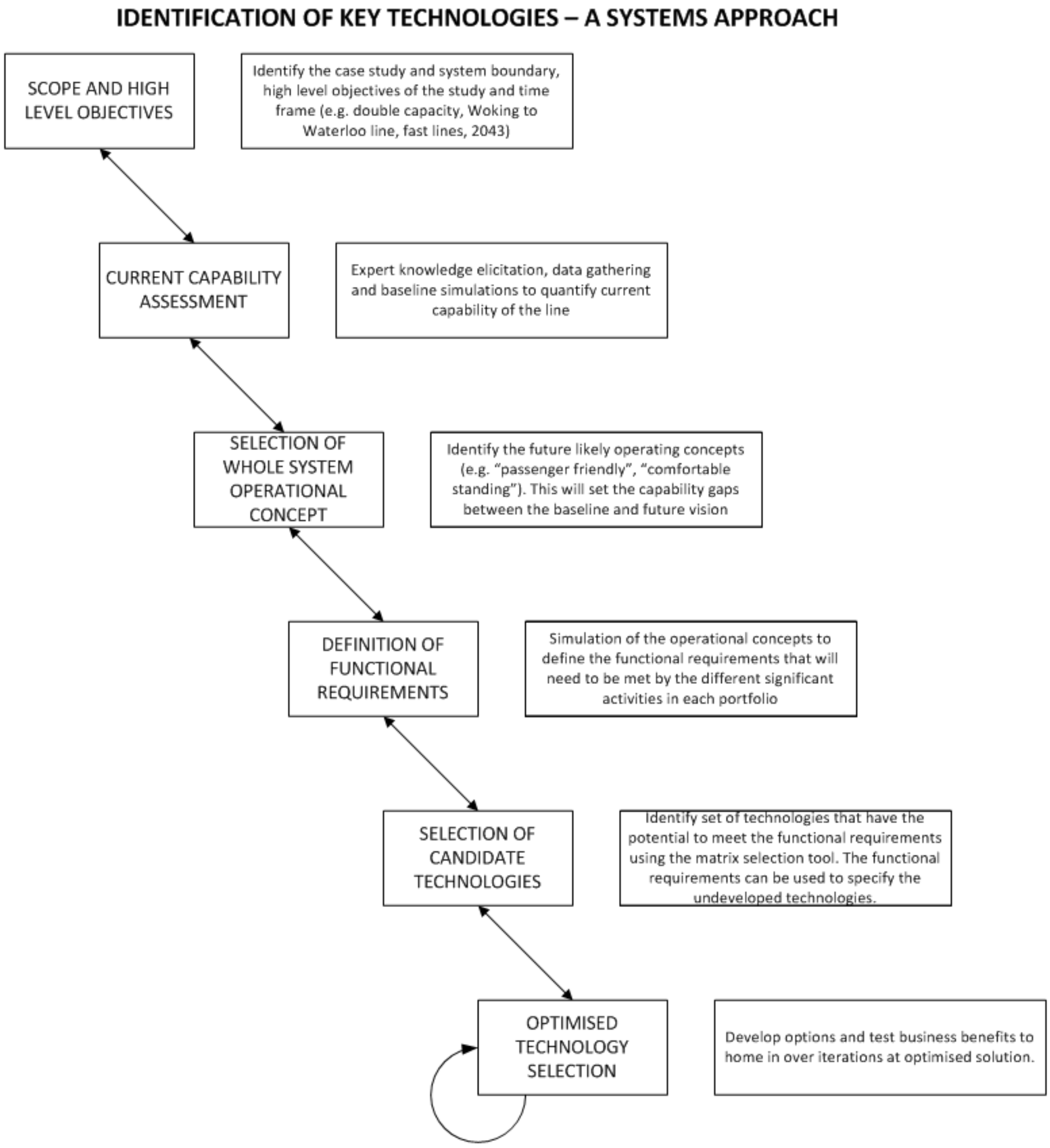


Figure 12: Whole-systems approach to capability improvement

The high-level objectives in Capacity4Rail are the delivery of an affordable, high capacity network through increased resilience, adaptability and automation by 2050.

The capability assessment establishes the appropriate capabilities (key variables) for the representation of the system being modelled, their current values and the anticipated capabilities of the future railway. Information on the system being analysed can be combined, bringing together expert knowledge and data on the existing and predicted future rolling stock, infrastructure and operational configuration.

Operational concepts then allow different visions for the railway of the future to be represented and compared, covering the whole system and setting different overall goals.

Each operational concept can be represented as a set of capability gaps, how each capability would be expected to change from a defined baseline to a selected operational concept. These gaps can be represented on a capability diagram, as shown (as an example only) in Figure 13; each operational concept will have a different "shape". This establishes the functional requirements that would be required to deliver the high-level objectives. These will provide specific values for the capabilities (e.g. one functional requirement could be the need for a signalling headway of 60s), based on the overall shape defined for the operational concept in question.

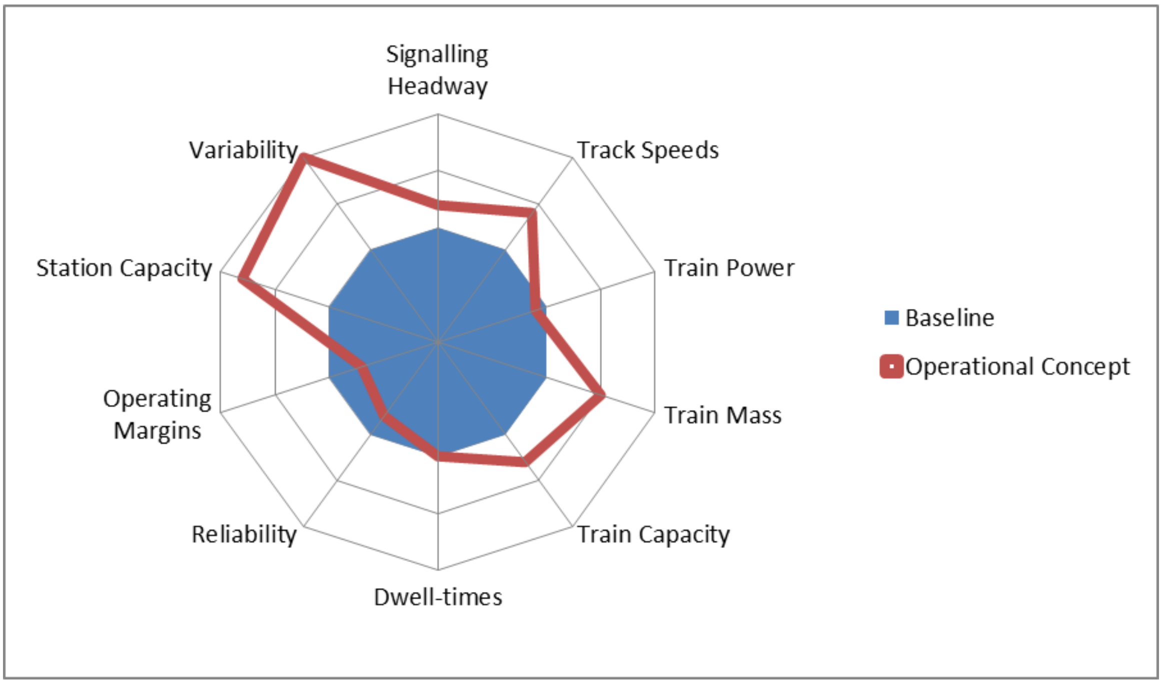


Figure 13: Example capability gaps for an operational concept

Note that all capabilities are shown such that an improvement is closer to the edge of the chart; for example, Figure 13 shows: a decrease in train mass and variability; no change to dwell-times; and an increase in track speeds and operating margins.

Part of the exercise within Capacity4Rail will be to develop the set of capabilities that will be represented, appropriate minima and maxima for the functional requirements based on the objectives and technologies within Capacity4Rrail and the appropriate operational concepts for comparison.

While the many factors that affect capacity, from individual train performance to high-level policy decisions, are recognized and understood, there is limited knowledge of the overall picture and limited experience of how trade-offs could best be made to deliver optimal solutions.

Broadly speaking, there are a number of possible metrics which could be used to assess railway capacity, including:

- Trains per hour (TPH);
- Number of passengers and/or tonnes of freight moved;
- Number of train paths for dominant vehicle – standard paths; and
- Point-to-point (node-to-node) journey times.

And the factors that affect capacity include:

- Rolling stock;
- Train power (acceleration and top speed);
- Train length (per-train capacity, platform lengths);
- Braking systems (braking distances, block size, headway); and
- Automation;
- Signalling;
- Headways;
- Timetabling;
- Stopping patterns;
- Stations;
- Platform availability; and
- Dwell times; and
- Track infrastructure;
- Track layouts, station throat, etc.; and
- Switches and crossings.

Operational misalignments also lead to a reduction in available capacity, and these can include:

- A lack of top-level approach, resulting in different sections of the network being modified in isolation;
- Institutional issues and industry fragmentation (multiple parties with different objectives);
- Conflicts resulting from different parties using the same line (e.g. passenger, freight, open access operators, etc.);
- Misalignments between operational concept and actual demand;
- Disconnect between planning and operations (e.g. seconds used for design while timetable is in minutes);
- Crewing policy and plans (e.g. split/join trains, crew location, poor communication and understanding and lack of correct tools); and
- Poor operational understanding of the differences between passenger and freight requirements.

The development of a matrix of capability interdependencies (see example shown in Figure 14) could be the first step in developing a model to assess the optimal trade-offs between the capabilities identified.

					Existing Condition (Value)	Railway Line Capacity									Overall Impact Score	Feasibility for Improvement			Combined Impact and Feasibility Score
						Infrastructure Capacity or Timetable Capacity (Trains/hour)							Train Capacity (Passengers or Tonnes/Train)						
						Usable Capacity	Minimum headway time	Regular recovery time	Dwell time	Waiting time	Buffer time	Special recovery time	Train capacity (Carriages-Wagons/train)	Carriage-Wagon capacity (Spaces/carriage or Tonnes/wagon)		Contextual (G / I / B)	Financial (H / M / L)	Technical E / D)	
						10	3	1	1	1	2	1	5	3					
Rail system	Railway Infrastructure	Track	Track Utilisation (CUI or Trains/track/hour)																-
			Track condition	Track Structure (Line Speed, mph)															-
				Min Curve (m)															-
				Max Gradient															-
		Station	Platform Utilisation (Trains/platform/hour)																-
			Platform Length																-
			Passenger Handling Facilities																-
		Junction Characteristics																	-
		Distance between Stations/Junctions																	-
		Power Supply																	-
		Signaling																	-
	Vehicle Fleet	Train Heterogeneity (Max/Min Speed Ratio)																	-
		Train characteristics	Train Utilisation (Seat Occupancy)																-
			Car / Wagon Characteristics	Carriage Utilisation (Seat Occupancy)															-
				Door Characteristics															-
			Braking System (braking rate)																-
	Operations	Safety Rules																	-
		Priority Rules																	-
		Traction Type																	-
		Environment Protection Rules																	-
		Station Stops																	-
		Public Performance Measure of Feeding																	-
		Timetabling Techniques																	-
		Maintenance Strategy																	-

Figure 14: A matrix of capability interdependencies

3 PLANNING METHODOLOGIES AND STRATEGIES

3.1 NATIONAL PLANNING

3.1.1 UK NATIONAL INFRASTRUCTURE PLAN

In 2013, the UK Government published a National Infrastructure Plan (NIP), setting out a decade-long plan for capital investment in infrastructure of all kinds (including, for example, energy and flood defences as well as transport). In terms of setting an objective for transportation, the plan describes a requirement for *“an integrated transport system that provides reliable, cost-effective domestic and international connections for organisations and individuals”*. The overall strategy for infrastructure investment laid out in the plan has four main aims:

Meet current demand through the renewal of existing infrastructure;
Meet future demand;
Grow a global economy; and
Address climate change and energy security.

In specific railway terms, the plan notes that:

Passenger demand is largely driven by commuter needs, both in terms of demographic shifts and congestion on other modes of transport. Commuting is increasing as more and more jobs are located in regional centres, and other forms of transport, such as roads, are seen as less attractive. Freight demand is growing due to a shift from the use of roads to rail for transportation.

The Office of Rail Regulation (ORR) estimates that there will be a 14 per cent increase in demand from passengers over the next five years, while there will be an overall increase in tonne kilometres of freight of 3 per cent annually to 2033 and 2.9 per cent to 2043, putting additional strain onto the system.

Much of the infrastructure that supports the network is already nearing its capacity limits. Commuter services into London and other regional centres are already oversubscribed, meaning that capacity is set to become an increasingly prominent issue over the coming years.

3.2 IM PLANNING

Capacity4Rail Milestone MS3 (“Specification of modelling tools and simulations”) covers, amongst other things, processes for IM timetable planning; the relevant portions of that document are summarized here.

3.2.1 RAILNETEUROPE

RailNetEurope (RNE) is an association, made up of IMs and Allocation Bodies (ABs), that aims to enable fast and easy access to the European rail network by supporting RUs in their international activities and effectively acting as a single European IM.

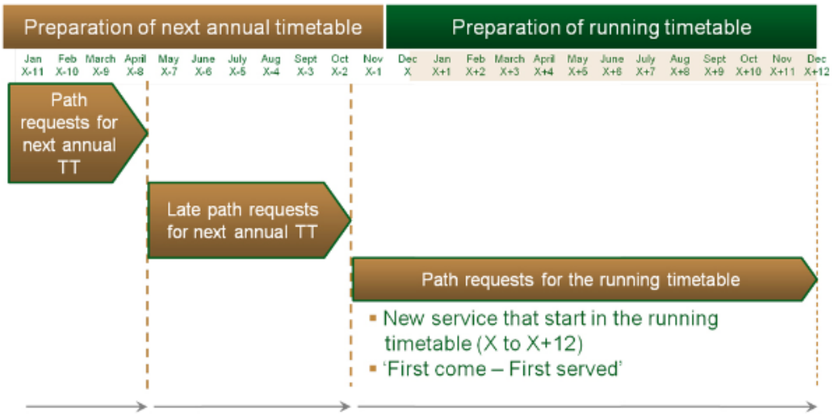


Figure 15: RNE Timetabling Process

The timetabling process used by RNE is shown in Figure 15. Late and ad-hoc requests can be made, but earlier requests have a higher priority.

3.2.2 GREAT BRITAIN

Timetabling in Great Britain works on three timescales:

Long-Term Planning (LTP): produces two timetables per year (starting in December and May), completed 26 weeks prior to introduction (i.e. as one timetable is released, the next should already be complete);
Short-Term Planning (STP): changes to timetables at least 18 weeks in advance, including trains that missed the LTP deadline and Network Rail applications for engineering access; and
Very short-term planning: timetable changes can be made in the Integrated Timetable Planning System (ITPS) up to 17.00 the day before the service is due to run, or directly into the Total Operations Processing System (TOPS) after that, where very short-term changes are needed.

Additionally, **ad-hoc planning** is used when the timetable cannot be carried out, due to the incidents that occur in daily operations; operational controllers and signallers regulate the timetables in real time to minimise disturbance.

LTP and STP use a "bid and offer" process, wherein RUs make bids for track access and are made responding offers by the IM.

Freight operators operate in a competitive environment, both between freight operators, as well as against strong competition from road haulage. The latter is particularly fierce, as shippers do not need to make any upfront investment to use the road network, and network access costs to road hauliers are not comparable to the access charges freight operators pay, both in terms of size and predictability. Rail freight also suffers from the disadvantages of not providing end-to end journeys, difficulty in competing for train paths with passenger trains, greater barriers for mixed traffic operations and, in general, the lower levels of technology development (e.g. braking characteristics, noise, speed, etc.). Three main challenges facing the Rail industry in terms of increasing the modal share of freight are[2]:

Need to strengthen co-operation between Infrastructure Managers on key aspects such as allocation of paths, deployment of interoperable systems and infrastructure development;
Finding the right balance between freight and passenger traffic along the Rail Freight Corridors, giving adequate capacity for freight in line with market needs and ensuring that common punctuality targets for freight trains are met; and
Promoting intermodality between rail and other transport modes by integrating terminals into the corridor management process.

3.2.3 Sweden

RUs apply for paths on the Swedish rail network and timetables are coordinated by the IM, which assesses whether the service plans are reasonable and feasible. The application period begins in April each year, and an iterative process is used to develop an initial proposal in early July then a final timetable in mid-September. This timetable fixes both occupied and unoccupied train paths, so for ad-hoc requests the IM suggests unoccupied train paths from the annual timetable.

3.2.4 Germany

Again, RUs submit requests for paths in April and a provisional draft annual timetable is developed by early July. Minor timing alterations can be made to resolve conflicts without involving the RUs; if significant changes are needed (3 minutes for passenger trains, 15 minutes for freight) then the RUs are consulted. Once the draft is published, RUs have a week to accept the paths they are offered. Ad-hoc allocations can be made up to three days in advance.

[2] http://www.rne.eu/rail-freight-corridors-rfcs.html

4 TARGETS, OBJECTIVES AND SCENARIOS

The following were identified as principal references in C4R Deliverable D5.1.1 ("Railway road map – paving the way to an affordable, resilient, automated and adaptable railway").

4.1 EUROPEAN RESOURCES

4.1.1.1 EC White Paper 2011: Roadmap to a single European Transport Area 2050

This Paper sets targets for (*inter alia*) (a) a reduction in transport-related greenhouse gas emissions, (b) a modal shift of freight from road to rail and/or waterways, (c) a modal shift of medium-distance passenger travel from road to rail, (d) expansion of the European high speed rail network, (e) the completion of the TEN-T core network - including rail links to core airports and core seaports, and (f) implementation of ERTMS. These specific targets, and other outputs and aspirations stated in the White Paper, have been incorporated into the roadmaps provided in Chapter 6.

With the issue of this White Paper, the cornerstone of European transport policy and strategy, the collection of transport statistics for the EU diversified to include information that can help identify and model emerging trends and drivers.

4.1.1.2 New EC Infrastructure Policy

This reference provides maps of the nine major TEN-T transport corridors that will provide the backbone to the trans-European transport network. To help deliver this network, EC financing for transport infrastructure is to triple, over the period 2014-2016, to €26 billion. There are numerous links on the homepage of this document to EC infrastructure and transport policy matters.

4.1.1.3 European Railway Traffic Management Systems (ERTMS)

This project will enhance cross-border interoperability across Europe through the creation of a single standard for railway signalling and is expected to also contribute to significantly improving safety and capacity.

A press release, in 2013, states that ERTMS is to be in place across the core European rail network by 2030. The European Railway Technical Strategy (see section 4.2) predicts that

ERTMS will double capacity, halve costs, improve safety (making railway the safest transportation mode) and provide full interoperability across the TEN-T by 2030.

As part of initiatives being developed based on the UK Rail Technical Strategy, research is currently being carried out into the potential for even higher levels of ERTMS/ETCS, (for example level 4, where the communication is between trains rather than having central hubs).

4.1.1.4 European Neighbourhood Policy

The objective of this policy is to avoid divergence between an enlarged EU and its neighbours. The Policy covers a broad range of issues ranging from industrial and competition policy to climate change, and includes energy security, transport, and R&D. (The relevant Europa homepage provides several progress reports and updates on the implementation of this policy.)

4.1.1.5 Horizon 2020

Horizon 2020 is the EC's latest and largest research and innovation framework programme. One of the aims of this R&D programme is to put Europe at the forefront of innovation in many areas, including transport. Up to date information on the programme can be obtained from the home page[3]. Transport is covered under the link to Societal Challenges, and the **EC's Interconnected Policy Transport Policy** can be downloaded from the relevant link. The latter does not cover rail transport specifically but the policy states that the vision is to construct a smart, green and integrated transport network. Actions to deliver this policy are to focus on (a) resource-efficient transport, (b) better mobility, less congestion, more safety and security, (c) global leadership for the European transport industry, and (d) forward-looking activities to feed into future policy making. The associated home page for **Horizon 2020 work programme 2014-2015** invites proposals for (a) smart, cost-effective, high capacity, user-friendly rail infrastructure, (b) intelligent mobility management, (c) energy management (d) logistic services, and (d) new generation of rail vehicles.

4.1.1.6 Rail Route 2050: the sustainable backbone of the Single European Transport Area

As stated by its subtitle ("*An initial update of the ERRAC Vision for Railway Research and Innovation for the future of rail*") this document provides an update of ERRAC's priorities for research and innovation in line with the **EC White Paper 2011: Towards a competitive, resource efficient and intelligent transport system for 2050**. The document re-iterates the

[3] http://horizon2020projects.com/

targets given in the White Paper and the trends and aspirations given in others, such as the **UIC-CER 2010 Sustainable Mobility Strategy** (see UIC eNews Nr 216). The ERRAC document provides a comprehensive review of the research and innovation needs for EC funded research to deliver the vision of the White Paper. The priority areas for research are; intelligent mobility; energy and environment; personal security; safety and homologation; competiveness and enabling technologies; strategy and economics; and infrastructure. The **UIC-CER 2010 Sustainable Mobility Strategy** identifies trends in the following that are relevant to the operation of a railway; globalisation; demographics; urbanisation; scarcity of energy resources; climate change; limitations of natural resources; biodiversity; individualisation and changes in lifestyle; limited public funding; stronger regulations; and intermodal competition.

4.1.1.7 Shift2Rail

This seven year R&D programme of work, due to start in 2015, is concerned with the development and implementation of technological breakthroughs that will help improve rail services across Europe. The project is to be managed by public-private partnership. The project aims to deliver (a) a substantial reduction in the life-cycle cost of rail transport, (b) a substantial increase in rail capacity, and (c) a substantial increase in the reliability of rail transport systems. The programme is focused on five key areas; (a) improved quality of rail services – through the development of a new generation of cost-effective, reliable, high capacity trains, (b) increased rail capacity – through the development of better traffic management and control systems, (c) provision of high quality, reliable rail infrastructure – through the development of lower cost, lower noise, and intelligent infrastructure, (d) provision of integrated ticketing and journey planners – through improvements in information technology solutions and services, and (e) more cost-competitive rail services – through the development of improved logistics and inter-modal freight movements.

4.1.1.8 ECTP Roadmap for cross modal transport infrastructure innovation

In June 2012 it was agreed to form a joint task force, from the various ETPs for road, rail, water and air transport, to develop a roadmap on cross-modal transport infrastructure innovation. The joint task force has started to extract the research and innovation priorities that span the various modes of transport. The focus of the study is the performing infrastructure but in addition to covering the construction and maintenance of physical structures, the scope is to encompass (a) its supporting systems and services, and (b) governance, management and finance.

4.1.1.9 Moving towards sustainable mobility: A strategy for 2030 and beyond for the European railway sector

This document outlines how the rail sector should be performing, in environmental terms, in 2030 and 2050. It also sets out, for the rail sector, (a) specific targets and objectives to meet by 2030, and (b) more general visions for 2050. The reference includes technical annexes and roadmaps that provide a framework for rail organisations to develop long-term plans to meet the targets.

4.1.1.10 Living Rail – Challenge 2050: The rail sector visions – how can rail contribute to a Europe worth living in[4]

This reference describes the European rail sector's perception, vision and goals for the railway of 2050. This wide-ranging document considers value for money; performance; safety and security; consistency; capacity; connectivity; sustainable development; and personnel.

4.1.1.11 EUROSTAT (2013) and the EU Transport in Figures – Statistical pocket book 2013

These references provide detailed statistical information on European transport, including rail transport.

The statistics on rail transport provided in **EUROSTAT 2013** are drawn from two sources: (i) that on rail infrastructure, equipment, enterprises and traffic from returns to the Common Questionnaire (Eurostat/UNECE/ITF), and (ii) that on rail infrastructure (length – total, electrified, and with two or more tracks) from returns to the REGWeb questionnaire.

The **EU Transport in Figures – Statistical pocket book 2013** gives the following information for freight transport movements within the EU:

- 11% of all the freight was transported by rail, and 45.3% by road.
- In 2011, 420 billion tonne km of freight was transported by rail – much the same as transported in 1997.
- In 2011, 1734.1 billion tonne km of freight was transported by road - compared to 1350 billion tonne km in 1997.

[4] http://www.livingrail.eu/rail-in-europe-2050/transport-visions/visions-and-roadmaps-for-the-railway-sector

4.1.1.12 EU transport demands: trends and drivers. Routes to 2050

This document reviews the trends in EU transport, and identifies and analyses the main drivers that will affect the demand for transport in the EU in the long (2050) term. This document was produced as part of the project *EU Transport GHG: Routes to 2050?* that supports the EU's long-term objective for tackling climate change – the strategic target for 2050 is to limit global warming to 2°C. Although new EC policy measures have been formulated, which aim to control emissions from the transport sector, these are not part of a broad strategy or overarching goal. Thus the key objective of that project is to provide guidance and evidence on a broad-based policy framework for controlling greenhouse gas emissions from the transport sector.

4.1.1.13 Energy trends to 2030

This document, published by the European Commission Directorate-General for Energy in collaboration with Climate Action DG and Mobility and Transport DG, provides forecasts of energy use for all transport sectors up to 2030.

4.2 NATIONAL RESOURCES

4.2.1.1 The Future Railway: The Industry's Rail Technical Strategy 2012.

This document contains the technical strategy for the railway in Great Britain. The document includes a 30 year vision (railway envisaged in 2040) for six key technical areas: control, command and communication; energy; infrastructure; rolling stock; information; and customers. The document was produced on behalf of the GB rail industry by the UK Technical Strategy Leadership Group and therefore represents the collective UK industry view. The document includes high-level roadmaps for each technical area, but few targets against which progress could be measured. The strategy has been well received both in the UK and in Europe where it has been influential in shaping key European programmes, specifically the nascent Shift2Rail Joint Undertaking.

4.2.1.2 Network Rail Technical Strategy

This document was published in response to *The Future Railway: The Industry's Rail Technical Strategy 2012* and outlines Network Rail's (the GB rail infrastructure operator) research and development priorities and opportunities for the next 30 years and contains its strategy for delivering the future vision for the GB railway. The document is closely aligned in structure and scope to the GB industry strategy, but goes into greater detail around the main technical themes, safety, performance, customer experience, capacity, cost-efficiency and sustainability. The strategy includes indicative programmes of work and associated high-level assessments of industry benefits.

4.2.1.3 Rail Technical Strategy Europe

The European version of the Rail Technical Strategy was published by UIC in 2014. The overarching vision of the strategy is that *"The European rail sector is proud to be the global leader for rail transport because it adapts readily to technological and commercial opportunities, many of which span state and operational boundaries."* The rail system is decomposed into: control, command and communication; infrastructure; rolling stock; energy supply and consumption; railway people; information management; security; and safety, with a vision, objectives and enablers outlined for each.

4.2.1.4 European Railway Technical Strategy

The European Rail Infrastructure Managers (EIM) published a technical strategy in 2008, a "Technical Vision to guide the development of TSIs" (technical specifications for interoperability). This defines different categories of business, in both the passenger (e.g. high-speed, regional, tram) and freight (e.g. high-speed logistical freight, heavy freight) sectors, as well as types of network (e.g. tramway, heavy freight network, high speed network).

The strategy includes a "2035 Vision of the Network and the Railway sectors", which predicts, among other things, faster passenger trains, heavier freight trains (on separate lines), differentiated rolling stock to lower costs on regional lines and intelligent trains reducing the quantity of trackside infrastructure. It establishes an overall objective for reduced costs (of both infrastructure and rolling stock) and increased possibilities for cross-border trail traffic.

4.2.1.5 Deutsche Bahn Strategy DB2020

The Deutsche Bahn strategy focuses on the period to 2020. The strategy takes into account the customers, employees, environment and society. The "mega trends", which are addressed in the strategy, are globalisation, liberalisation, climate change, shortage of resources and demographic changes. Depending on freight or passenger transport or infrastructure different challenges and future targets are described.

The strategy for freight expects a growing European freight market of approximately 2% per year as a mean value. Big risks are the increasing volatility of European markets.

The protection of the environment is a key subject in the strategy for all assets and transport modes and it is expected to increase the acceptance of the railway system and strengthen the "green" position of its customers. Flexibility with respect to economic trends and changes is identified as a central success factor of the railway.

4.2.1.6 Plan de Infrastructuras, Transporte y Vivienda PITVI 2012-2024

This document, published by the Spanish Government (Ministry of Public Works), presents the strategic vision for all means of transport (rail, road, air and maritime transport), and also for housing. The document establishes the criteria to plan and prioritize the future investments in transport until 2024.

For railways, the targets identified in the document are to increase efficiency and competitiveness, to increase sustainability, to achieve a seamless chain of transport with other means of transport (inter-modality), to increase the efficiency and market share of freight traffic and to contribute to the cohesion of the Spanish regions. Some of the specific actions included in the plan include increasing the maximum length of trains up to 750m and the maximum load up to 22.5t in some lines to adapt them as European corridors.

Figure 16: Railway network proposed by the Spanish Government for the Trans-European Network

4.2.1.7 Plan Estratégico para el Impulso del Transporte Ferroviario de Mercancías en España

This document, produced by the Spanish Government (Ministry of Public Works), describes the actions that should be taken to move from the 2010 market share for rail freight transport (4.1%) to 8-10% in 2020. To achieve such targets the plan envisages liberalisation of the market, an increase in transport efficiency, the creation of logistical platforms, the adaptation of some railway lines to meet freight requirements and the use of emerging technologies, among others.

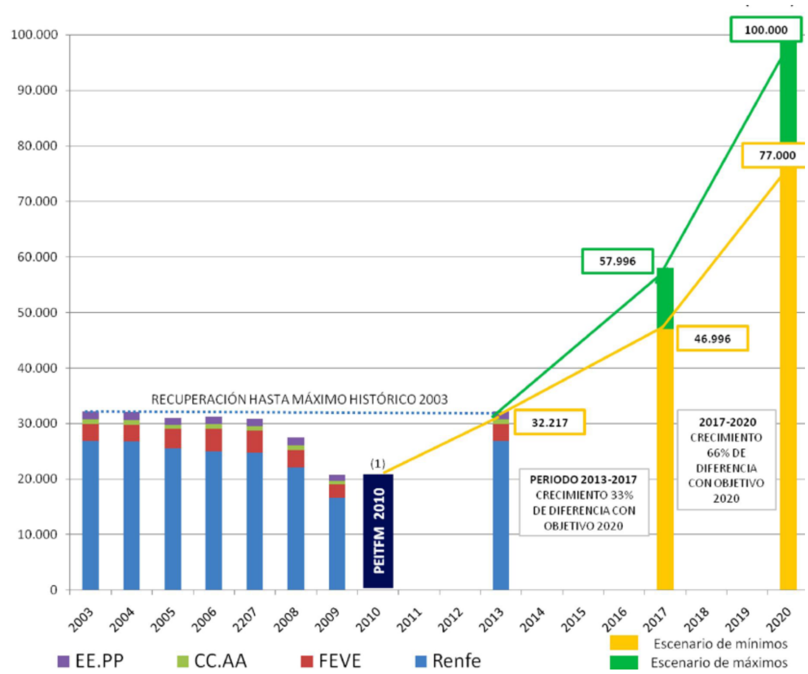


Figure 17: Estimated evolution of freight transport by rail from 2010 to 2020

4.2.1.8 Estrategia Logística de España

This document describes the strategy for Logistics in Spain. It meets the vision of the PITVI 2012-2024 plan and sets a roadmap for the future years to increase of efficiency of the transport, the inter-modality between modes of transport, etc. in order to enhance the logistic role of Spain in Europe. To achieve that, the document reveals a list of actions such as the creation/improvement of multimodal logistic platforms. Regarding the specific plans for railways, it envisages the creation of specific high capacity corridors, increasing the priority of freight trains when allocating slots, extending the rail network, etc.

4.2.1.9 Zielnetz 2025+

The strategic concept of ÖBB Infrastruktur AG is Zielnetz 2025+ (Target Network 2025+). The overall goal is to shift transport volume from road to rail with ambitious target setting such as 40% increase in freight volume, 30% increase in train-kilometres and a 25% percent increase in passenger volume by 2025+. This is expected to avoid 11.1 million truck-loads in Austria and increase the number of passengers from 240 to 300 million. Regarding ERTMS the strategy is to equip all major corridors (TEN-T) as well as new and refurbished lines.

4.2.1.10 Czech Republic Transport Policy Priorities

The following priorities follow from the global goal and are interlinked:

- Achieving a suitable modal split by ensuring equal conditions on the transport market;
- Ensuring quality transport infrastructure;
- Ensuring financing in the transport sector;
- Improving the transport safety; and
- Supporting transport development in regions.

4.2.1.11 Turkish State Railways Strategies

The TCDD strategy focuses on 2023-2035 period. In order to render TCDD more effective and efficient and to increase its share in passenger and freight transportation, projects such as high speed line construction, investments in conventional lines, renewal projects of existing lines and rolling stock, Electrification, Signalization and Telecommunication (EST) projects, new rolling stock procurement and establishment of logistic centres are being carried out.

TCDD’s major goals are as follows:

- Increasing the railway lines to 31,000 km by constructing 6,000 km new fast line between 2023 and 2035.
- The development of the railway industry and the marketing of railway products internationally.
- To improve intelligent transport systems and infrastructure for providing the railway network integration with other transport systems and development of international combined transport and effective supply chain management.
- Ensuring the completion of the railway lines and connections in the Straits and Gulf Crossing between the continents of Asia, Europe and Africa as a major rail corridor.
- Updating the legal and structural legislation in line with EU legislation for regulation of rail transport activities.
- Increasing the rate of railway passenger transport to 15% and freight transport to 20 %

5 STRATEGIES FOR DEALING WITH TEMPORARY VARIATION

5.1 ROAD

5.1.1 SMART MOTORWAYS

The Highways Agency (HA), which manages the UK's Trunk Road Network (TRN), has recently begun using "Smart Motorway" techniques[5] to increase the capacity of heavily-utilised motorways at peak times. The objective was to deliver increased capacity, particularly during high traffic flow periods, quickly and at lower cost relative to building new infrastructure. Different types of Smart Motorway include:

- **Controlled motorway**: speed limits for the running lanes can be reduced from the 70mph national speed limit using overhead Variable Message Signs (VMS); and
- **Hard shoulder running**: the overhead VMS indicates that the hard shoulder can be used by all traffic, providing a temporary extra lane.

An additional advantage is that these techniques allow the available capacity to be adapted to the prevailing demand.

5.1.2 OPERATION STACK

One strategy used when significant reduction in cross-Channel transport capacity is experienced is the UK's "Operation Stack", which involves using a section of the M20 motorway in South-East England to provide a parking facility for heavy goods vehicles. This strategy is used when events such as bad weather or industrial action prevent the use of one or more of the Port of Dover, the Channel Tunnel or the English Channel; for example, it was put into effect following the fire in the Channel Tunnel in January 2015. Other road traffic is diverted along the A20, which provides a parallel route; however, the operation causes significant disruption to other users of the road network, causing long tailbacks and loss of business. A similar strategy, albeit on a smaller scale, is also used at the ports of Felixstowe and Stranraer.

[5] http://www.highways.gov.uk/our-road-network/managing-our-roads/improving-our-network/smart-motorways/

5.1.3 AUTOMATION

In the roads sector, as in rail, there is a great deal of interest in the potential for automated and autonomous vehicle operation, including convoying of cars and self-driving vehicles.

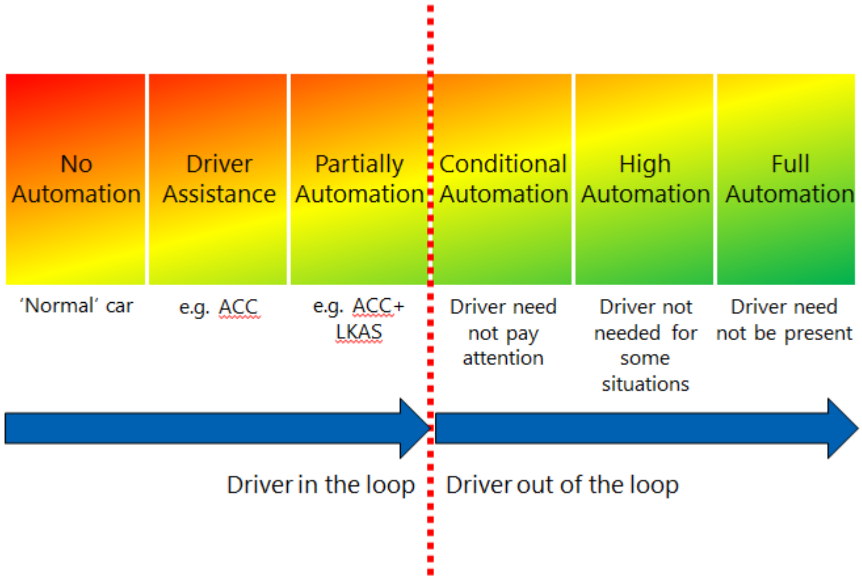


Figure 18: Levels of automotive automation (source: SAE International)

Increased automation reduces reaction times, allowing vehicles to operate more closely together and maximising the number that can be accommodated on a given quantity of infrastructure.

In the railway sector currently, automatic train operation (ATO) covers a range of levels of automation. However, as with aviation, the presence of a driver stationed in the cab at the front of the train is still seen as a necessity for main line operations. There is a recognition that the future of the railways is in automation, with driverless trains. This is still only an ambition, however, and technological and behavioural challenges will need to be overcome before it becomes a reality.

For example A vision for London 2050 [13] states "Driverless operation should be progressively introduced throughout London Underground, and as required or appropriate to Overground and other surface commuter trains to allow greater train frequency and increased capacity. On deep Tube lines passenger service agents should be employed for safety reasons".

5.2 TRANSPORT PLANNING

Although unforeseen events cannot, by definition, be explicitly prepared for, where there are circumstances likely to lead to an increase in the number of these events plans can be made to deal with them more effectively.

5.2.1 ALTERNATIVE TIMETABLES

One issue faced by many railways is autumn leaf fall, which can affect the wheel-rail interface and lead to low adhesion, for example causing an increase in the incidence of signals passed at danger (SPADs). It is common, therefore, for an alternative timetable to be published for the autumn and winter, where low adhesion may be more common, providing greater allowances. Although the specific incidents cannot be predicted in advance, the increased allowances help to ensure that the timetable can be maintained when they do occur. This leads to a significant reduction in theoretical capacity, as all services are affected even though not all may suffer from low adhesion-related incidents.

5.2.2 DEMAND MANAGEMENT

When demand is projected to be particularly high, for example when there are significant numbers expected to travel to public events (e.g. Olympic Games), steps can be taken to reduce other demand. For example, during the London 2012 games, the expected increase in the number of passengers was managed by warning passengers not attending the games (e.g. commuters) in advance to avoid travelling during the events whenever possible, reducing one source of demand so that the other could be adequately catered for. Extensive public transport provision meant visitors were transported to the game by train, bus, metro, light rail and underground rail, and built-in resilience meant that if one part of the network failed or was disrupted passengers could be redirected via other modes. As one report[6] puts it:

The overall planning was guided by a policy established at the very start by the London bid company and carried through by the Olympic Delivery Authority and LOCOG (the London Organising Committee of the Olympic Games): Transport to the Games would be by public transport only, wherever possible, making use of existing infrastructure and building new only where it was 'essential and leaving a lasting legacy'.

By contrast, extensive new infrastructure was built to manage transport demands during the Athens 2004 games.

[6] http://www.itsinternational.com/categories/detection-monitoring-machine-vision/features/success-of-londons-olympic-public-transport-systems/

5.3 EXTREME WEATHER

The FP7 EWENT project [14] defined extreme weather events as follows:

Extreme events are generally rare events. The events cause the exceeding of maximum values and/or pre-existing (measured) high (low) thresholds of certain weather parameters and generate impacts that are harmful to any part of the transport system (infrastructures, operations, vehicles, passengers or cargo).

Extreme weather events can include: heat waves (high temperatures and either high or low humidity); cold waves (rapid fall of temperature, low temperatures, heavy and persistent snow, unexpected freezes and frosts); high winds; and high levels of precipitation (high rainfall, flash floods).

Extreme weather events can cause significant impacts to rail services. For example, the extreme winter conditions in Northern Ireland in 2010/11 (average December temperature of -0.6°C) caused 12% of NI Railways' services to be delayed or cancelled [15]. To mitigate the weather impacts, major works including installation of heating elements in high-risk crossing barriers and points machines, building up reserve stocks of de-icing products, training additional reserve staff and improving rolling stock to reduce issues with freezing overnight were carried out. As a result, during cold weather in March/April 2013, relative delays and cancellations were reduced by two thirds.

The threat posed by extreme weather events, and which types of event should be planned for, varies by prevailing climatic conditions. EWENT proposes a classification of European countries into climatic zones, grouping those which are at risk from similar types of extreme weather, see Figure 19 [14].

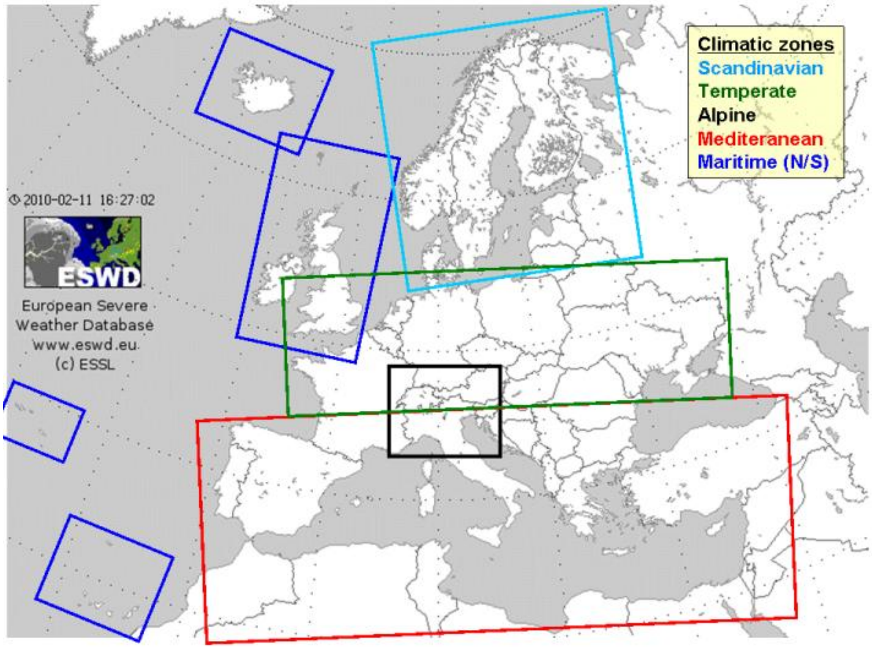


Figure 19: Classification of climatologically simlar regions

There is ongoing work investigating the resilience of transport networks to extreme weather events. The British government recently completed a transport resilience review [16], to help prioritise efforts and good practices to ensure that transport operators and authorities can learn from their own and others' experience and ensure that, when there is disruption, the duration and impact are minimized. Another FP7 project, RAIN[7], is aiming to *"quantify the complex interactions between weather events and land based infrastructure systems"* (across the transportation, energy and telecommunications sectors) and aims to aid long-term decision making through the development of an operational analysis framework.

[7] http://rain-project.eu/about/

6 INTERACTIONS WITH OTHER TRANSPORT MODES

6.1 JOURNEY PLANNING TOOLS

6.1.1 PASSENGER

There are many passenger-focussed online journey planning tools.

6.1.1.1 Public sector

In the UK, the Department for Transport, Welsh Assembly Government and Scottish Government co-fund Transport Direct[8], an online, multi-modal, door-to-door journey planner for Great Britain. Unlike other services, this allows the comparison of different modes of transport on a cost or even carbon emissions basis, including fuel cost estimations for car journeys.

6.1.1.2 Private sector

Google Maps now includes transit directions for many cities across Europe and further afield[9], allowing simple multimodal journey planning for users of the website or smartphone applications, alongside the existing road directions.

There are commercial systems to do this planning, too; for example, many European rail systems (including DB and ÖBB) and other transport authorities (e.g. the City of Stockholm) base their online journey planners on the HaCon HAFAS system[10] .

6.1.2 FREIGHT

There are several freight routing tools with a road freight focus.

[8] http://www.transportdirect.info/web2/home.aspx
[9] http://maps.google.com/landing/transit/cities/
[10] http://www.hacon.de/hafas-en

6.1.2.1 Public sector

Transport for London has an online Freight Journey Planner[11] for road freight in London, allowing freight hauliers to plan routes based on information about accessibility, road works, temporary restrictions, etc.

6.1.2.2 Private sector

PIE also provide a road Freight Journey Planner[12], which is dedicated to HGV route planning. This tool uses Navteq and Local Authority-submitted restriction data to avoid inappropriate routes for large vehicles.

Paragon[13] are another provider of fleet route planning. Their customers include the UK's Royal Mail postal distribution service.

[11] http://freightplanner.tfl.gov.uk/user/freightJourneyPlanner.php
[12] http://www.piegateway.com/products/fjp/about-FJP/
[13] http://www.paragonrouting.com/uk

7 CONCLUSION

The overarching needs of the 2050 railway system are recognised across the European countries to be: high capacity; low cost; reliability and seamless integration with the broader transport network. However, it is clear that to achieve this across Europe requires a holistic, whole-system approach, rather than the current segmented approach, e.g. route-level planning, which leaves lots of gaps. Operational misalignments, industry fragmentation and disconnect between planning and operations are significantly impacting on the available capacity on the

The capability of the transport network to meet the growing demands being placed upon it is a growing concern. In addition to congestion on the road networks, crowding in public transport (road and rail) is becoming a serious issue. In the case of railways, the reality is that the demand, particularly in the passenger sector, is not evenly distributed on either a spatial or a temporal basis. Recent years have seen significant growth is some sectors, routes, times of day etc. For example, where commuters are the primary consumers, services have become extremely overcrowded during peak hours. There are numerous examples of excessive crowding on a number of routes. Crowding has effects on railway operations (e.g. operating speeds, dwell times, travel time reliability and modal choice) as well as the passengers (e.g. well-being and value of time) and it is therefore crucial to understand where, when and why railway capacity is needed.

At present detailed and accurate understanding of available capacity, usage and predicted growth in the different European countries is lacking. It is also clear that there is no single view on the key drivers of capacity constraints, and that the changes that would deliver capacity improvements are strongly influenced by the particular characteristics of a line/route. An improved understanding of current capability gaps is required to better match supply with demand and deliver a service that is valued by its customers. Analyses of the utilisation of the capacity being delivered by the system can help identify crucial bottlenecks.

These views also suggest that the capacity could be significantly improved by adopting technology solutions e.g. ETCS to reduce the amount of capacity lost to dated signalling practices. Additional technology improvements, more smart monitoring and increasing automation of operations could move usable capacity towards or even up to the theoretical maximum. As part of the Capacity4Rail study, one aspect would be to investigate increases in the level of automation in operations to deliver some of this potential increase in capacity. For example, timetable planning is a relatively slow process, whether operating at the national level (by IMs) or the international level (by RailNetEurope); timetables are developed months in advance of operation. There is still little automation in the planning process, particularly in terms of ad-hoc changes during operations (e.g. response to disturbances).

In terms of the stated targets, objectives and scenarios developed by national and international bodies, drawing on the resources identified in D5.1.1 we can see an ambition for increased modal share for the railways and integrated transport at the European level. However, the national responses to that ambition are varied; many countries have individual aims to shift traffic, particularly freight, to the railways, but most are focused on the situation at the national level. For international integration, it will be necessary to encourage member states to think strategically, considering the railway in its context as a pan-European transport network, and plan accordingly.

The transportation system is vulnerable to extreme weather events like heat waves, high winds and heavy precipitation, which can result in significant direct costs to the IMs, operational costs to the RUs and customers through disruption and, if not well-handled, reputational damage to the service providers. However, these events are not evenly spread, and what is considered an extreme event in one location is business as usual in another. Although the experience to meet the challenges of 'extreme' is out there, there appears to be limited knowledge transfer and sharing of experience. Applicability of external experience is also constrained by national standards, priorities, perceptions etc. Greater efforts are beginning to be expended on helping to share good practices across Europe, and ensuring that appropriate lessons are learned and shared from each experience but structured, collated information on causes, costs and impacts is not currently available. Strategies for dealing with sudden unexpected temporary variations in demand are still in the early stages of development on both railways and highways. Although alternative timetables can be introduced to account for seasonal variations in condition, for example, this is inflexible (due to the length of the planning cycle), significantly reduces capacity (as the more conservative timetable is not always needed to maintain operations) and is not always robust (as conditions worse than those planned for may still occur). Automation offers one solution to this problem, allowing operational changes to be made in a much more dynamic manner, to respond to changing conditions.

Another key ambition for the transportation sector overall is the seamless, end-to-end journey, where customers are able to access the right mode of transport in the right place at the right time, optimising their use of the various modes available to them while minimising the cost and effort required. Again, although this is being addressed, the effort is piecemeal. The development of tools for journey planning, across both freight and passenger traffic, is a major area of innovation, driven by the growth in the use of mobile computing devices like smartphones and the growing quantity and availability of data, and some modal interchanges are being optimised (e.g. synchronising timings between buses and trains), but these activities are happening in separate silos.

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