C4R
Capacity for Rail

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

Interim milestones to achieve step-changes in Railway capacity and performance for passengers and freight

Submission date: 27/11/2017

Deliverable 51.2

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 605650

Collaborative project SCP3-GA-2013-60560
Increased Capacity 4 Rail networks through enhanced infrastructure and optimised operations
FP7-SST-2013-RTD-1

Lead contractor for this deliverable:

- DB AG

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Acronyms and Abbreviations

The following list provide definitions for acronyms and abbreviations and for terms used in this document:

CBA	Cost-Benefit Analysis
IMs	Infrastructure managers
IWW	Inland Water Way
LCC	Life-Cycle Costs
PAP	Pre-Arranged train Path
RAMS	Reliability, Availability, Maintainability and Safety
RFC	Rail Freight Corridor
SWOT	Strength, Weakness, Opportunities and Threat
3ARC	Affordable, Adaptable, Automated, high Capacity

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Executive Summary

The aim of this deliverable is to point out interim milestones that are necessary to achieve step changes in railway capacity and performance for passengers and freight.

The report will summarize the results that were achieved in the project. It will try to answer "What will an adaptable, automated, resilient and high-capacity railway look like and how to pave the way?"

This deliverable provides a list of milestones that are necessary to achieve step changes in railway capacity and performance for passengers and freight. As future visions are difficult to express in formulas a method was searched to guide the development and prioritization of milestones. Targets are an affordable, adaptable, automated, resilient and high capacity railway system. As appropriate methods, SWOT-GAP[1] and bottleneck analyses were selected. The SWOT analysis is easy to use and takes beside the strength and weakness of the railway system also the opportunities and threats into account. Where strength and weakness describe the actual situation and bottlenecks of the railway system the opportunities and threats can be interpreted as future demands. In order to capitalise on the strengths and opportunities and address the weaknesses and threats, the European rail sector needs to become more efficient, integrated, modern and responsive to customer demand.

As the rail network cannot be improved in isolation specific milestones may depend on the local boundary conditions and other transport modes. This deliverable therefore summarizes no specific but more generalized milestones. From these "global" milestones more specific ones can be derived by a bottleneck analysis on real sections or corridors (task 5.3.2). From these milestones scenarios can be compiled that take into account the innovations to develop in SP1 to SP4.

The analyses point out important milestones to achieve an adaptable, automated, resilient and high-capacity railway like

- Reliable and available infrastructure
  - Slab track or improved ballasted track
  - Improved S&Cs
  - Monitoring of critical assets to know about the state
  - Predictive maintenance
  - Availability to operate long freight trains
- Improved freight trains
  - Automatic couplers
  - Low noise breaking system for freight trains
  - Long trains with distributed locomotives
  - Increase axle load
- Improved operation
- System and Standardization
  - Gauge
  - Power supply
  - Train control system

[1] SWOT means **S**trengths, **W**eakness, **O**pportunities, **T**hreats

- Seamless border crossing

Lots of these milestones like ETCS level 2 or gauge which are necessary for seamless, high capacity transport in Europe are pointed out too but they are not in the focus of the project.

1 Objectives

The objective of this deliverables is to describe the results of task 5.1.2. This task was to develop milestones, scenarios and innovations that bring together those developed in the other 4 SPs and ensure progress towards a common goal of increasing capacity for passengers and freight through improved technologies and operations.

This task therefore has to enable the integration of the work within the sub-projects and the individual WPs through agreement with SP- and WP leaders and a prioritization of topics and ensure a Systems Approach to delivering capacity across the European Railway Networks. Figure 1 illustrate the task 5.1.2 in context to the other SP5 work packages and SP1 to SP4. The input for task 5.1.2 should come from WP 5.1, task 5.2.1 and from the SPs.

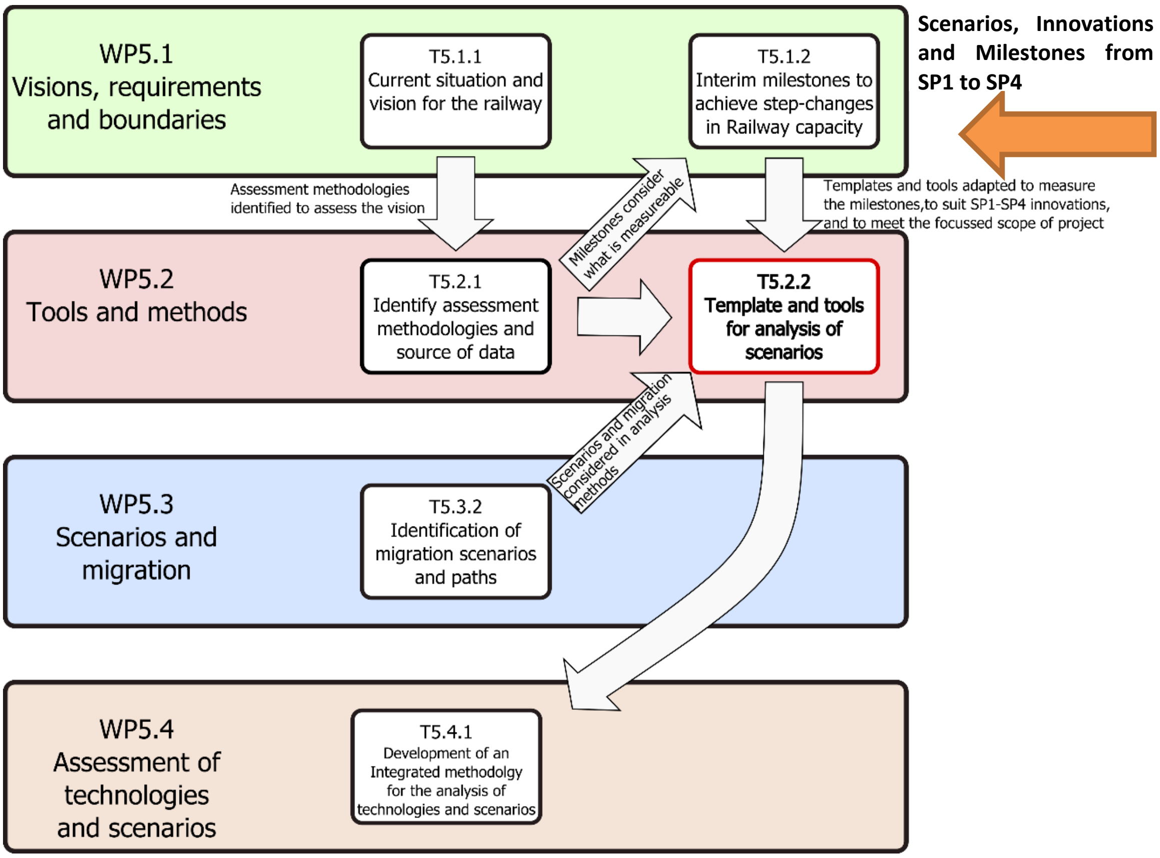


FIGURE 1–TASK 5.1.2 WITHIN THE CONTEXT OF OTHER SP5 WORK PACKAGES AND SPS (SOURCE: D 5.2.2)

This deliverable provides a list of milestones that are necessary to achieve step changes in railway capacity and performance for passengers and freight. As future visions are difficult to express in formulas a method was searched to guide the development and prioritization of milestones. Targets are an affordable, adaptable, automated, resilient and high capacity railway system.

As mentioned in the Executive Summary, a SWOT-GAP and bottleneck analysis were selected to identify and prioritize milestones.

2 SWOT-Analysis

As mentioned above a SWOT-analysis is a common method to analyse the strengths, weakness, opportunities and thread of product, system or in this case transportation mode for strategic decision. Figure 2 shows in a tree diagram the result of the SWOT-Analysis carried out in task 5.1.2.

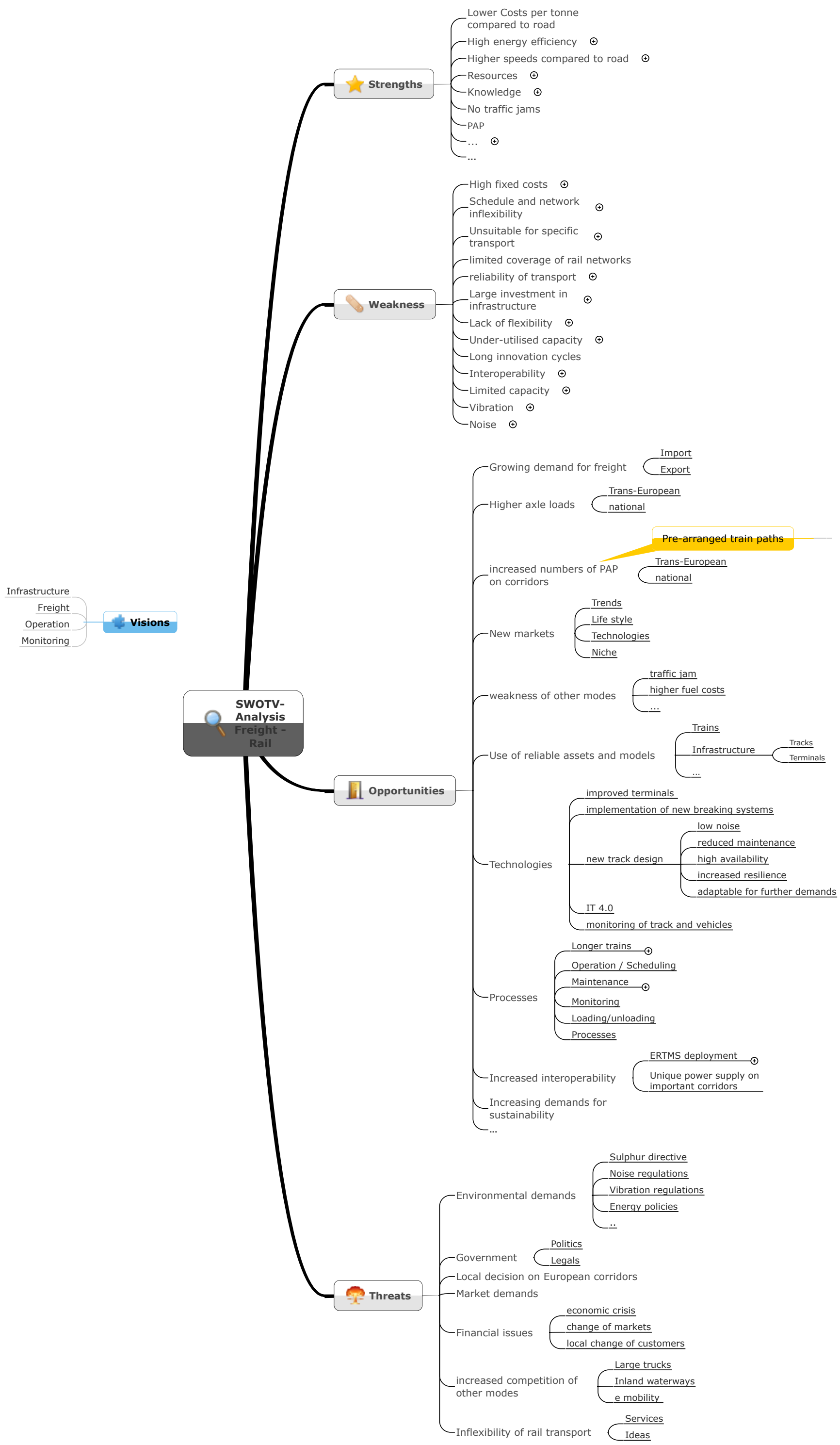


Figure 2 – Tree diagram of the SWOT-Analysis

The following sections describe the results of the SWOT analysis carried out in more detail. Most information gathered from project information like roadmaps, developed in task T5.1.1 and from literature survey [1-15]. In general, the lists are not sorted with respect to importance.

The following abbreviations are used to assign the topics to the project targets.

A1 – Affordable, A2 – Adaptable, A3 – Automated, R – Resilient, C – High capacity

2.1 Strengths and Advantages of Railway System

- Lower costs (per tonne) compared to road for long-distance transport (A1)
- Higher capacity than road (C)
- Multimodal services are faster in most countries (C)
- Sustainable solution (A1)
- Intra-modal competition improves the productivity of the freight rail market and stimulates new market activities
- International pre-arranged freight train paths (C,R)
- Flexibility in the definition of reserve capacity for ad hoc requests (A2,R)
- High safety level
- Energy efficiency (A1)
- Higher speeds and economical solution for longer distances (A1,C)
- Environmentally friendly (A1)
- No road traffic (A3,C)
- No driving bans (e.g., Sundays, holidays) (C)
- Low carbon (A1)
- Less land take (A1)
- Cross boarder & cross stakeholders collaboration (C)
- Part of TEN-T Core Network (A1)
- Broad variety of intermodal connections to the hinterland with short transit times in Central Europe (A1,C)
- Increased capacity (ferry's, new railroads, new areas in ports etc.) (C)
- Good logistical know how

Advantages

1. Dependable

The greatest advantage of the railway transport is that it is the most dependable mode of transport as it is the least affected by weather conditions such as rains, fog etc. compared to other modes of transport.

2. Better Organised

The rail transport is better organised than any other form of transport. It has fixed routes and schedules. Its service is more certain, uniform and regular as compared to other modes of transport.

3. Higher Speed over Long Distances

Its speed over long distances is more than any other mode of transport, except airways. Thus, it is the best choice for long distance traffic.

4. Suitable for Bulky and Heavy Goods

Railway transport is economical, quicker and best suited for carrying heavy and bulky goods over long distances.

5. Cheaper Transport

It is a cheaper mode of transport as compared to other modes of transport. Most of the working expenses of railways are in the nature of fixed costs. Every increase in the railway traffic is followed by a decrease in the average cost. Rail transport is economical in the use of labour also as one driver and one guard are sufficient to carry much more load than the motor transport.

6. Safety

Railway is the safest form of transport. The chances of accidents and breakdowns of railways are minimum as compared to other modes of transport. Moreover, the traffic can be protected from the exposure to sun, rains, snow etc.

7. Larger Capacity

The carrying capacity of the railways is extremely large. Moreover, its capacity is elastic which can easily be increased by adding more wagons. Frees up capacity on existing lines so that future demand can be carried by rail rather than being forced back to road by overcrowding. It also provides more rail freight capacity.

8. Environment

Particularly safe, rail is environmentally friendlier and less polluting than other modes of transport . A significant advantage at a time of increasing congestion on Europe's roads and growing public concern about environmental issues. Provides a low carbon alternative for long distance travel, supporting other policy measures to restrain car and aviation (see Opportunities).

Weakness of road > strength rail?

- Limited transport volume (C)
- Traffic jams (A1,C)
- Legal restrictions (A1)
- Weather effects (R,C)
- Restrictions on transport of hazardous goods (C)
- Ecological aspects (A1)

2.2 WEAKNESS

- Physical bottlenecks and missing links in the rail network (C)
- Punctuality and reliability are still weak elements (due to works and weather conditions) (R,C)
- Logistics processes less transparent
- Technical parameters for the rail network are not optimised (A,R,C)
- Fragmented volumes and empty wagons (C)
- Terminal capacity varies (C)
- Limited capacity in number of trains per day (depending on day/ month) for specific sections (C)
- Capacity limitations due to high passenger demand as well as infrastructure-related issues like works in the corridor (A2,C)
- No alternative routes (A,R,C)

- Customs/administrative barriers (varying processing times in borders) (A3,C)
- ERTMS currently at 12% (200x) (A3,C)
- Longer trains can only operate in a few parts of the corridor (A1,C)
- Limited maximum speed and low average speed (C)
- Limited multimodal links to ports (A2,C)
- Long innovation cycles (ARC)
- High fixed costs (A1)
- Schedule and rail-network Inflexibility (A2)
- Inadequate for short-distant transports or with frequent cargo changes
- Monopolistic position of the main operator
- limited coverage of railway networks (A2)
- inability of rail to accommodate a significant transfer of traffic from other modes without massive investment in additional capacity (A1)
- „single degree of freedom mode of transport‟ (A2,R)
- vulnerability of railway infrastructure and operations to changing weather patterns (A1,R)
- rail has significant weaknesses in terms of its ability to adapt to the effects of climate change (A,A,R)
- insufficient — and decreasing — investment
- Uncertainty about cargo; its owners, origin and destination
- Unbalanced cargo flows
- Underdeveloped connections
- Trust in the quality railroad, brand
- Insufficient strategically work among stakeholders
- Economic challenges due to different technical & administrative systems
- Priority of passenger services on railway (A1,C)
- Lack of flexibility in relation to the car (A2)
- Expensive with road/rail in relation to maritime
- Need of ice-breakers and ice-classed vessels during winter months
- Noise impacts on communities along route, which increase with speed. (A!)
- Community severance.
- High carbon impact in constructing new lines (A1)
- Few stations on route limit transport benefits to communities directly along route. (A2,C)
- Cross-sections of tunnels (A1,C)
- Increased environmental impacts (noise, carbon, pollution, energy consumption) with increased speed and capacity (A1,C)

Disadvantages

Although railway transport has many advantages, it suffers from certain serious limitations:

1. Huge Capital Outlay

The railway requires is large investment of capital. The cost of construction, maintenance and overhead expenses are very high as compared to other modes of transport. Moreover, the investments are specific and immobile. In case the traffic is not sufficient, the investments may mean wastage of huge resources.

2. Lack of Flexibility

Another disadvantage of railway transport is its inflexibility. Its routes and timings cannot be adjusted to individual requirements. Certain lack of dynamism, reliability, flexibility and customer orientation on the part of railway undertakings. At times the political influence on the railway business is too strong, while there is still insufficient interoperability between national rail systems as well as

3. Lack of Door to Door Service

Rail transport cannot provide door to door service as it is tied to a particular track. Intermediate loading or unloading involves greater cost, more wear and tear and wastage of time.

The time and cost of terminal operations are a great disadvantage of rail transport.

4. Monopoly

As railways require huge capital outlay, they may give rise to monopolies and work against public interest at large. Even if controlled and managed by the government, lack of competition may breed inefficiency and high costs.

5. Unsuitable for Short Distance and Small Loads

Railway transport is unsuitable and uneconomical for short distance and small traffic of goods.

6. Booking Formalities

It involves much time and labour in booking and taking delivery of goods through railways as compared to motor transport.

7. No Rural Service

Because of huge capital requirements and traffic, railways cannot be operated economically in rural areas. Thus, large rural areas have no railway service even today. This causes much inconvenience to the people living in rural areas.

8. Under-utilised Capacity

The railway must have full load for its ideal and economic operation. As it has a very large carrying capacity, under-utilisation of its capacity, in most of the regions, is a great financial problem and loss to the economy.

9. Centralised Administration

Being the public utility service railways have monopoly position and as such there is centralised administration. Local authorities fail to meet the personal requirements of the people as compared to roadways.

2.3 Opportunities

- Growing demand in the corridor
- Shift to long-distance transport
- Growth in containerised transport
- ERTMS deployment
- Improve technical parameters (including speed and punctuality) to make rail more competitive for medium and long distance trips
- Capacity growth for specific section with current and forecasted bottlenecks
- Higher fuel costs have a high impact on road operating costs
- New multimodal sites are implemented
- Port plans promoting multimodality to increase the share of rail next to inland waterways

- Longer trains can lower the costs for transportation of automotive or combined traffic
- New services due to intra-modal competition
- Improve the interface between terminal operators and IMs
- Communication and cooperation among all the rail operation parties/harmonised methods, processes and tools commonly defined by IMs from all corridors
- Further implementation of “One Stop Shop” applying harmonised concepts for international capacity allocation on every freight corridor
- Increase PAPs in the corridor
- Increasing penetration of market through joint ventures
- Entering to other markets
- Expanding product and service line
- Growing export and production of natural resources, mining products, bulk goods in north
- Accessibility to new market
- New possibilities for import
- Competitive intermodal price levels
- Efficient solutions
- New working places
- Standardization, best practice, networks
- Increasing interest in railway investments
- Cooperation on new networks
- Future regulations will have positive impact
- Sulphur directive
- Improved sustainability of railway system
- Improved design of infrastructure with respect to environmental issues, capacity and modal shift
- New routing on important corridors avoiding sensitive areas
- Increased charging of road use

2.4 Threats

- Financial issues due to the economic crisis limiting the investment on rail or providing less subsidies for rail
- Capacity issues in main stretches; currently present in specific and a projected over-utilisation for the whole of the corridor
- High competition from inland waterways for shared commodities due to terminal capacity, barge capacity and low costs
- Larger trucks taking over the long-distance share for rail
- Noise regulation impeding the growth for rail freight services
- Energy policies favouring renewable energy sources
- Slowdown in economy
- Increasing fuel prices

- Intense competition
- Sulphur directive
- Non-flexible logistics branch; “old tracks” The more complexity the harder to change
- Finance crises
- Partly poor and insufficient infrastructure but good logistics knowledge vs. an inflexible branch
- Political and legal structures
- Governmental sub optimization and financial incentives that govern errors
- There has been no continuity in efforts to secure corridors to Russia
- Cross-border competition between modes of transport, both between battles and between countries
- Rebounds effects undo modal shift benefits
- Improvement of other modes like driverless operation of cars, reduced fuel consumption or XXL trucks

2.5 SWOT-Matrix

The SWOT- Matrix combines on one hand the strengths with opportunities and threats and on the other hand the weakness with opportunities and threats. These combinations can be used to identify and prioritize fields of action.

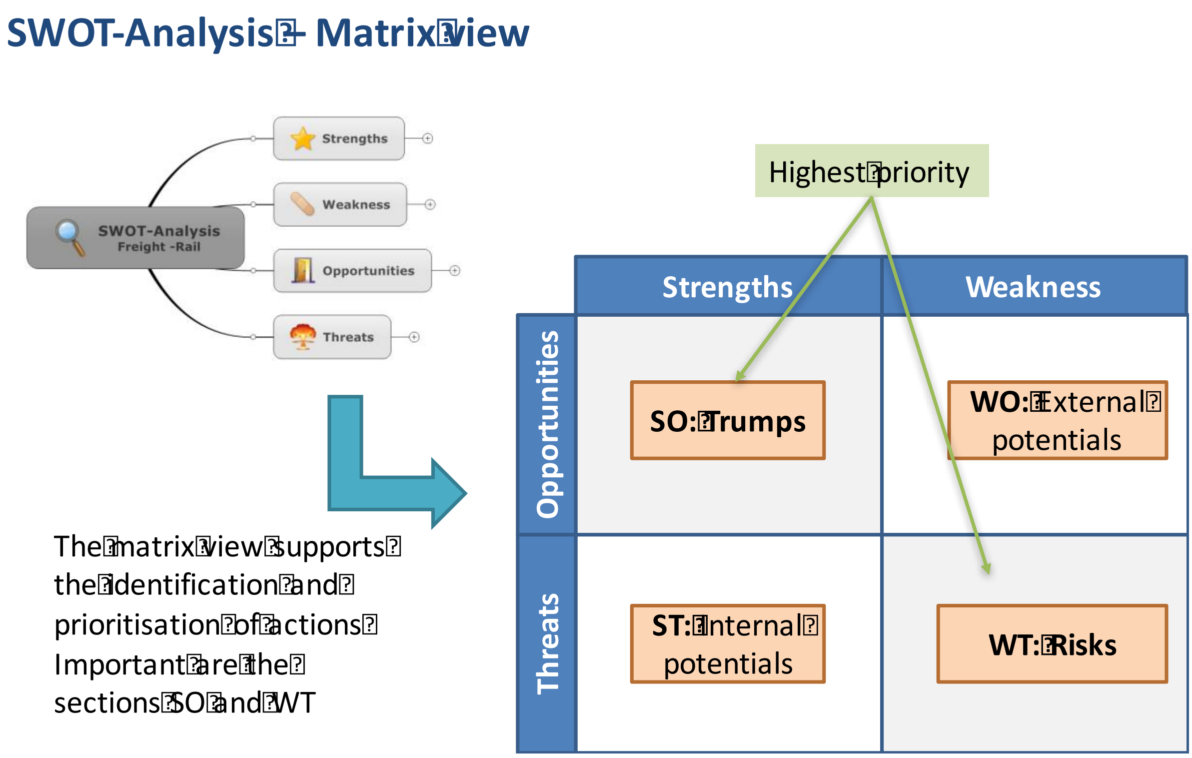


FIGURE 3-MATRIX VIEW OF SWOT ANALYSIS – STANDARD VIEW

In the first step the gathered results are arranged in the matrix structure shown in Figure 3.

The combination of strengths and opportunities (SO) indicates activities with high positive impacts and should be taken into account in either case.

The combination of weakness and threats (WT) indicates issues with high negative impacts and should also be taken into account to overcome the weakness and the resulting risks and to increase the image.

The rearrangement in the structure of shown in Figure 4 allows a more detailed usage of the result.

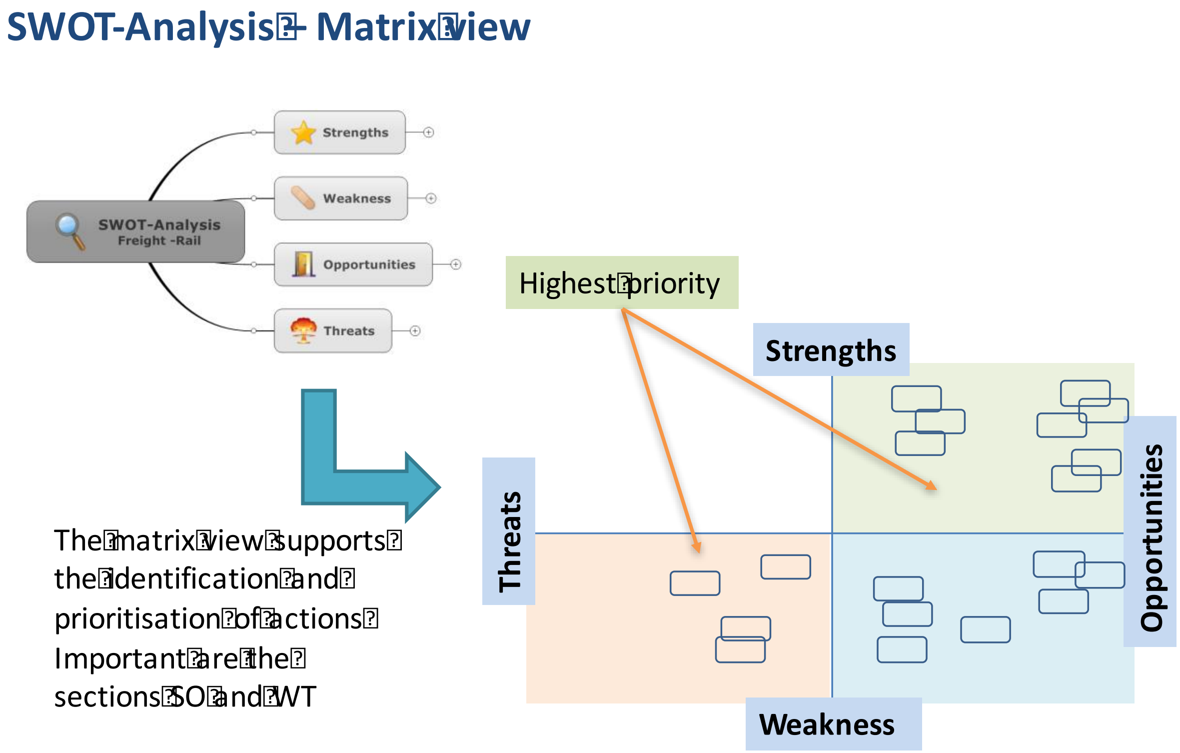


FIGURE 4-MATRIX VIEW OF SWOT ANALYSIS – EXTENDED VIEW

Benchmark for the criteria's and their ranking (strengths and weakness) is on the one hand the comparison with the competitors and on the other hand the future requirements which are documented in the roadmaps.

3 Customers view on transport modes - KPI

Figure 5 shows a simple assessment of different transportation modes made by customers with respect to following KPI's

- Transport time,
- Adherence to delivery dates,
- Transport costs,
- Flexibility and
- Network density.

FIGURE 5–ASSESSMENT OF DIFFERENT TRANSPORT MODES WITH RESPECT TO KPIS

It is obviously that the transport time and flexibility are the weakest points of rail transport from customer perspective. Only the density of the network is less and therefore better than for the road.

These results are in good agreement with the detailed SWOT-Analysis. The results of C4R address the KPI transport time and transport costs. Flexibility are not in the focus of C4R but indirect addressed in SP3.

4 Bottlenecks

Generally, bottlenecks can be defined as

a) sections on corridors, where the total traffic demand of freight and passenger trains exceeds the available capacity including consideration of capacity used for maintenance works per section
b) interoperability – time consuming, resources,
c) national regulations – speed restriction , cross sections, …

Figure 6 shows the bottlenecks, which are marked in red, on the Rail Freight Corridor 1 in 2012

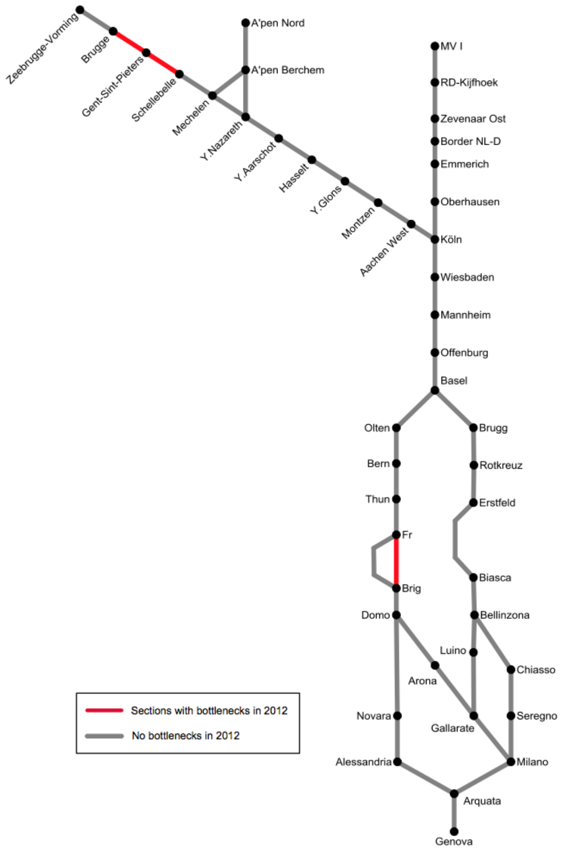


FIGURE 6– *BOTTLENECKS ON RAIL FREIGHT CORRIDOR 1 – RHINE – ALPINE #1*

The analysis of bottlenecks must take into account future demands and requirements like change in markets,

Looking at the freight transport the following major bottlenecks are raised

- Interoperability especially with respect to
  - power supply,
  - train control systems,
  - train length,
  - maximum axle loads or
  - border crossing

- Noise and ground bourn vibrations in particular with respect to further demands
- Cross section of tunnels
- Capacity

Figure 7 illustrates a general European problem at the example of power supply and train control system. Due to historical reasons a lot of different systems are available. The interoperable operation requires therefore more expensive trains.

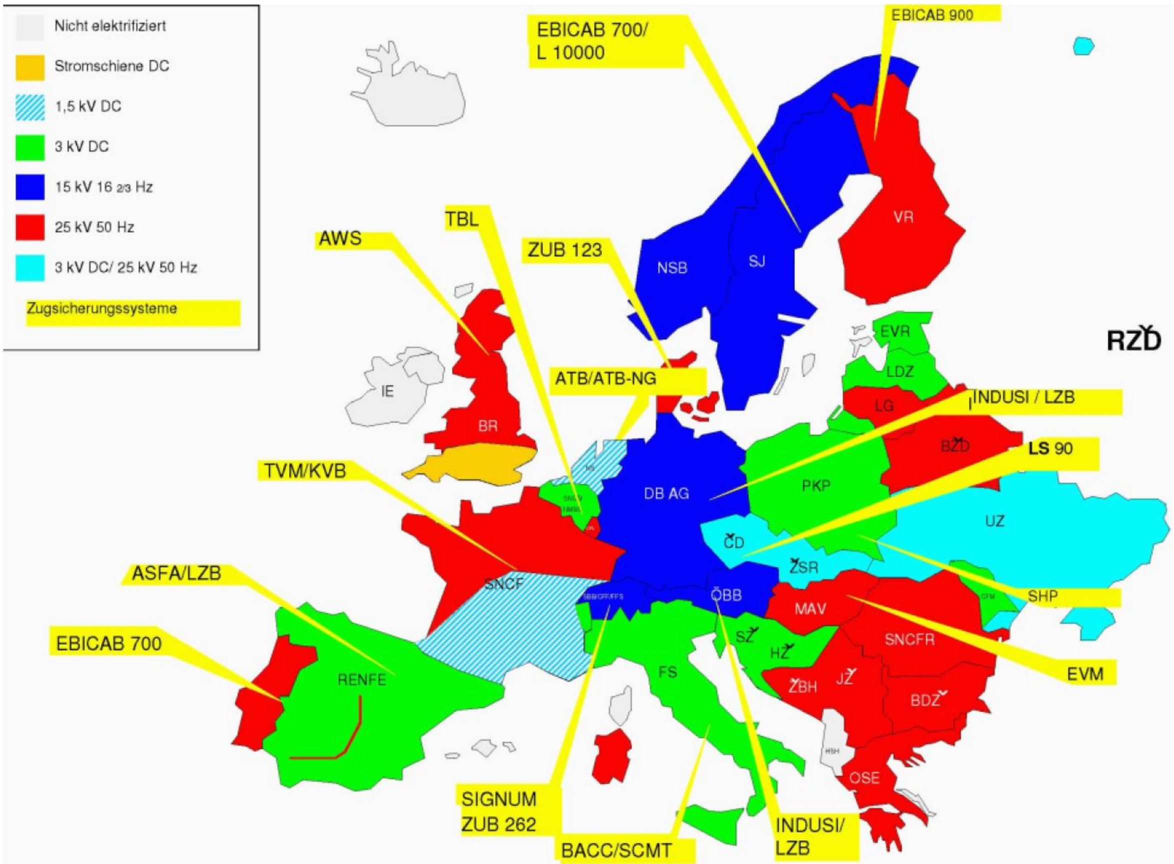


FIGURE 7– *POWER SUPPLY AND TRAIN CONTROL SYSTEMS IN EUROPE*

4.1 Bottlenecks on ScanMed Corridor

Looking at the rail freight corridor 3 (ScanMed corridor), the situation is similar with the European one. **Figure 8 to Figure 10** show the different power supply systems, train control systems and the implementation of ERTMS. Particularly aggravating in view of the power supply systems are the sections without electrifications.

The implementation of ERMTS on the whole corridor will reduce the effort for the corridor, but the connection outside the corridors will raise the issue again.

To overcome such interoperability problems huge investment are required that challenge the economy of the railways. Also, future updates of "European solutions" like upgrading the ERTMS level need additional investment in infrastructure and rolling stock.

This is one of the greatest problems for railways. Looking at the main competitor - the road - the same truck can drive in all different European countries without to change the technique. It is clear, that a funding by European Commission is necessary to make step changes in the area of railways.

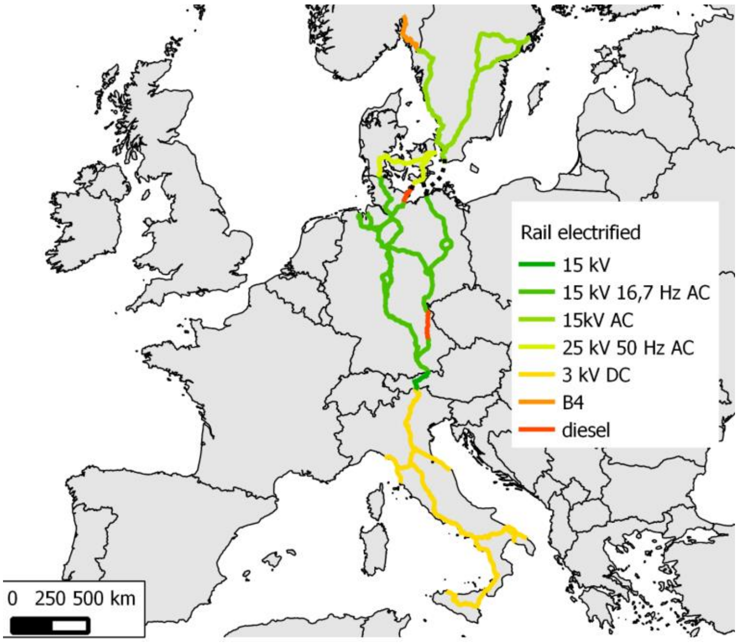


FIGURE 8–*DISTRIBUTION OF POWER SUPPLY SYSTEMS ON RCF3,* SOURCE: SCANDINAVIAN-MEDITERRANEAN CORRIDOR PROJECT

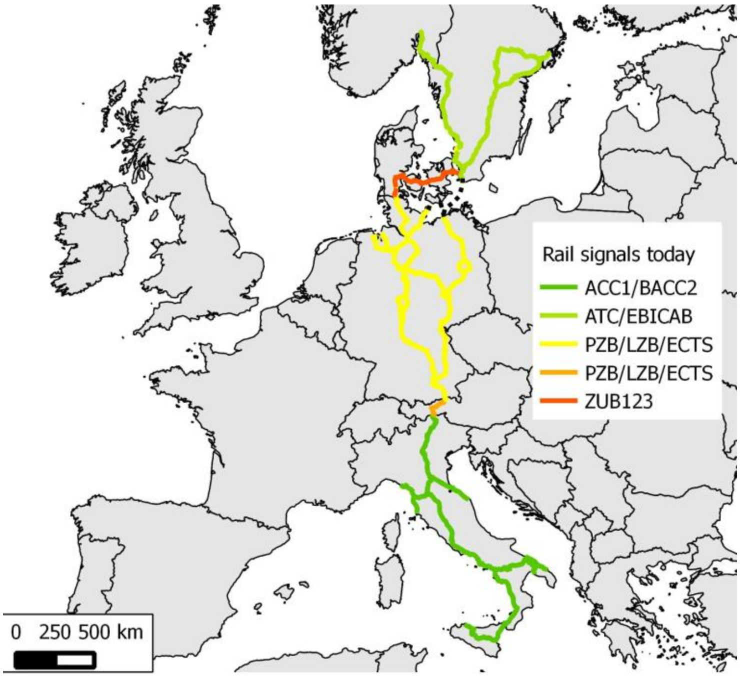


FIGURE 9–*DISTRIBUTION OF TRAIN CONTROL SYSTEMS ON RCF3,* SOURCE: SCANDINAVIAN-MEDITERRANEAN CORRIDOR PROJECT

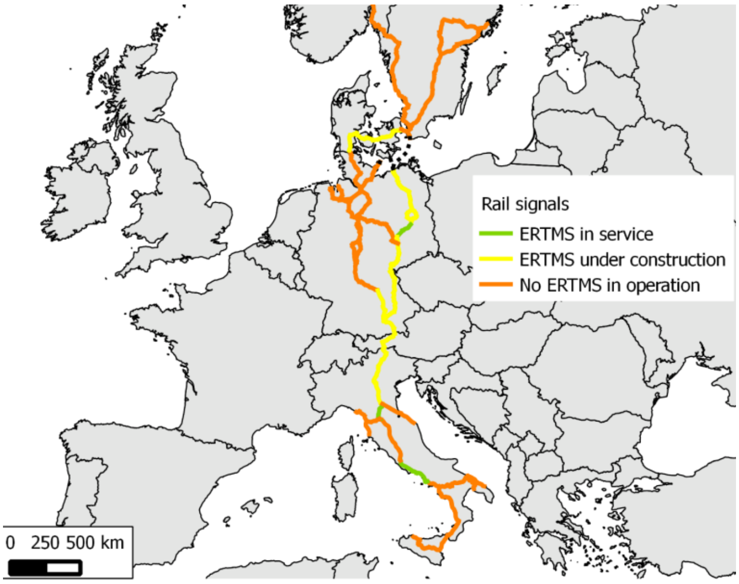


Figure 10–*Distribution of Train Control Systems on RCF3,* Source: Scandinavian-Mediterranean corridor project

4.2 Bottlenecks on Rhine-Alpine Corridor

The following **Table 1** summarizes bottlenecks on the Rhine-Alpine Corridor and the timing for removal.

TABLE 1-RAIL PROJECTS TO REMOVE BOTTLENECKS ON RHINE-ALPINE CORRIDOR CAUSING CAPACITY ISSUES

No.	Costs (M €)	CC	Location	CB	Study or Works	Description of project	Timing
5	157 – 420	NL	Rotterdam Port (europort) - Zwijndrecht		Study	Caland railway bridge, upgrade, new construction or diverting route (incl. study and works)	2015-2020
10	935.5	BE	Brussels-Denderleeuw (L50A)		Works	Increase in capacity of the Brussels - Denderleeuw line: building of 3rd and 4th tracks	2014-2017
26	402	IT	Milan: Rho-Gallarate		Study and works	The project involves the installation of a fourth track, alongside the railway line between the stations of Rho and Parabiago. The upgrading of the railway link allows to increase the current capacity.	2014-2020
27	30	IT	Chiasso-Milano	part	Study and works	Technology upgrade regarding headways for additional capacity, needed for the traffic increase forecasted by an IT-CH forecast	2016
28	70	IT	Parabiago-Gallarate		Study and works	Technology upgrade regarding headways for capacity increase	until 2020
29	n/a	IT	Genoa-Milan; Genoa-Novara		Study and works	Speed upgrade (infrastructure and technology) in order to reduce travel time between the main urban nodes.	until 2020
34	371	IT	Novara - Oleggio	part	Study and works	2nd track Vignale - Oleggio	until 2020
36	300	IT	Genoa-Milan		Study and works	Upgrade to 4 tracks on link Milano Rogoredo - Pieve Emanuele	until 2020
50	160	IT	Genoa - Milan; Genoa - Novara; Novara - Domodossola ; Milano - Chiasso	part	Study and works	Removal of critical rail crossings on various sections	until 2020
9	289	BE	Brussels railways		Works	Capacity increase of the North-South Junction in Brussels	2014-2025
11	463	BE	Gent - Zeebrugge		Works	Increase in capacity of the Gent-Zebrugge line: creation of 3rd and 4th track between Gent and Brugge and a third tracks between Brugge and Dudzele and various extension works (ports of Zeebrugge and Gent)	2014-2025
12	2,012	DE	(Amsterdam)-Zevenaar-Emmerich-Oberhausen (1. stage)	part	Works	Upgrade of existing line (third track)	2005-2023

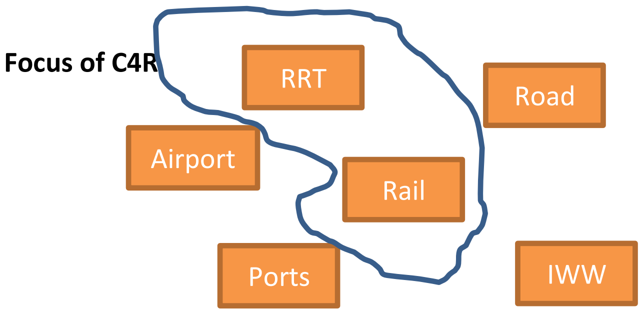
32	600	IT	Tortona - Voghera		Study and works	Upgrade to 4 tracks	until 2025
35	164	IT	Oleggio - Arona	part	Study and works	2nd track	until 2030
51	600	IT	Genoa - Milan		Study and works	Upgrade to 4 tracks on link Pavia - Pieve Emanuele	until 2025
54	n/a	IT	Rho - Gallarate		Study and works	Stations and headway upgrades for capacity increase	2025/2030
2	20	NL	Utrecht - Arnhem		Works	PHS (Programme High-Frequent Rail Services) to increase the capacity/reliability on the section Driebergen-Zeist;Ede	start before 2020
3	234	NL	Utrecht - Arnhem - German border	part	Works	Improve the conventional line capacity	2009 - unknown
4	703	NL	Meteren		Works	Building Meteren Boog to connect the Betuweroute with existing network to intensify rail freight on the Betuweroute	start before 2020
15	2,000	DE	Düsseldorf-Duisburg a. nodes Rhein-Ruhr-Express		Works	Resolution of physical bottlenecks (passenger) and upgrade of nodes	unknown
18	6,172	DE	Karlsruhe-Offenburg-Freiburg-Basel (1.stage)	part	Works	New line and upgrade of existing line (third and fourth track)	started-unknown
19	n/a	DE	Karlsruhe-Offenburg-Freiburg-Basel (2.stage)	part	Works	New line and upgrade of existing line (third and fourth track)	unknown
56	326	IT	Rho - Gallarate		Study and works	Upgrade to 3 tracks on the railway line between the stations of Parabiago and Gallarate, and completion of "Y link" ("Raccordo Y") in Busto Arsizio. The project aims to improve rail service to Malpensa Airport and along the rail line Rho-Gallarate.	after 2030
57	1,412	IT	Chiasso - Milano	part	Study and works	Upgrade to 4 tracks on the railway line between the stations of Chiasso and Monza. The project allows an increase of capacity, in view of the expected traffic from Gotthard tunnel.	after 2030

Source: Information from national Ministries of Transport and infrastructure managers

The bottleneck analysis clearly shows, that a lot important constraints are not related to the work in C4R. Here we have to concentrate on infrastructure improvements, trains concepts and improved operation control.

5 Visions and bottlenecks for a 3ARC railway

The visions for the railway in 2030 or 2050 are strongly influenced by the visions for other transport modes like road, air or water. For a sustainable and economic transport in Europe the strengths of the different modes should be considered and combined to a seamless functioning of all modes and multimodal chains for passenger and freight transport.



Visions should be described in a general way because then they describe a more general situation in Europe. The derived specific and technical objectives and milestones then strongly depend on local boundaries and requirements. E.g. a European Rail Traffic Management System like ERTMS level 2 may be necessary to maximize the capacity on corridors and to mix high speed passenger trains and low speed freight trains. On a commuter line classical traffic control systems are sufficient and much more affordable. But both types of line have to fulfil the same requirements in transportation quality expressed by reliability, punctuality or customer information.

Therefore due to different requirements and boundaries it is nearly impossible to draw one common figure for a railway system which is affordable, adaptable, automated and resilient and that fulfils demands for high capacity. As the criteria ADAPTABLE, RESILIENT and AUTOMATED are often in contradiction to an AFFORDABLE system the need for different solutions is obvious. Like the decision “make or buy” the solution changes with real requirements and boundaries.

The work in Capacity4Rail will not cover all modes but is focussed on parts of the railway system and the rail/road terminals (RRT).

As mentioned above the strengths of different modes should be taken into account to achieve an affordable transport in Europe. For freight transport this will mean to use the rail and Inland Water Ways (IWW) for long and medium distances and the road for medium and short distances and the supply to the customer and the terminals.

Looking at the objectives of C4R in terms of adaptable, automated, resilient and high capacity the following visions could be drawn. Not all the visions may be affordable but this depends on the requirement of the customers.

The loading of the corridor varies very much throughout the corridor, with main bottlenecks at the borders and around key nodes.

The corridor as such is seldom used as one transport core, especially not for road transports.

Terminals are in general considered the main bottlenecks, among others because they typically are located close to the nodes, where traffic by all means is heavy.

Railway freight transport is facing challenges; increasing prices, congestion, technical cross-border barriers and not full and open competition. In Germany, according to the project partners’ assessment, there seems to be a positive tendency as to long-distance rail freight getting more competitive.

Technical harmonisation on weight, profile and length of axles, wagons and trains are to be standardised throughout EU. It can also be added that technical certifications (e.g. for rolling stock) obtained in one country should be valid in other EU-countries also.

One-stop-shops for ordering slots at the freight corridor(s) to be fully harmonised and include slots at terminals to sustain on time and tracked deliveries.

Moreover, in order to achieve a “green” corridor, energy efficiency (fuel infrastructure, e.g. filling stations), and good flow on the corridors are important (transport without stopping along the corridor). To support such a development, adequate infrastructure and a business model are necessary.

In connection with the realisation of a “green” corridor, it is also considered to be of great importance that there is focus on the customer needs and planning is not done against the customer. This is an important aspect especially as to transport by rail – and necessary to achieve a higher market share of rail freight transport.

The general focus on national interests and the cheapest transport solution is a hindrance for the “greening” of the corridor though – national egoism, where many different players on the corridor can be an issue.

One stakeholder has explicitly mentioned that they are reducing the use of conventional rail because there are too many delays – transport by rail is seen as unreliable. It is pointed out that the rail system in Sweden is in bad condition, so that trains are often derailed. There are many single tracks in Sweden, and together with derailed trains this gives serious delays. There are often many types of problems with rails: Leaves on the track at autumn, frost in the tracks / switches etc.

One factor contributing to rail transport being seen as unreliable is that it is vulnerable for instance for storms and for repairs in general, as one stakeholder puts it. Last years, following a huge storm several places in Europe, no trains were allowed to leave Verona for several days, since the capacity was fully utilised. Here, it should be added that different stakeholders mentioned that rail transport is not reliable enough – independent of weather conditions.

A supplementary factor limiting the available capacity is that passenger and freight traffic share the same railway net along the corridor. A stakeholder mentions that rail freight in Sweden does not seem to have a bright future as freight trains are not given priority, which makes them unreliable. It is e.g. mentioned that passenger rail has increased for a long time now in Sweden. Passenger trains have priority over freight trains - like most of Europe. The consequence is that passenger transport is squeezing out freight transport on rail, as one stakeholder puts it. Adjacent to this comment is the remark that the economic value of freight trains is underestimated when conducting cost-benefit analyses.

In general, the stakeholders agree on that lack of necessary infrastructure and terminals may be an obstacle. This is an aspect underlined by different types of stakeholders and across the countries. In addition, some stakeholders mention that cross-border transport by rail is always more difficult to organize than transport by road.

The capacity at the terminals is a steady growing bottleneck

Another aspect is the non-predictability of the punctuality/delay of the trains. It is e.g. not possible to plan the handling process for the arriving trains. There is thus potential for optimisation. Moreover, the booking system for rail transport must include both the slots on the railway lines and the booking of terminal space. Hereby the terminal capacity can be monitored and fully exploited.

Another problem for the customers of the terminals is that often the capacity for stationing/parking wagons is too limited as mentioned by one interview partner. Therefore, some stakeholders affected look for new/bigger terminals

All in all, the stakeholders welcome improved competition on the different transport modes. To achieve this, a couple of conditions have to be fulfilled though. For rail transport it an e.g. be mentioned that tracking is a very important issue - it has to be as easy as it is on road today!

Additionally, the inclusion of external costs into the road transport costs is mentioned as a measure to possibly ensure a more balanced competition between transport mode

Some of the specifications and standards that would be important to harmonise as to securing a seamless cross-border transport along the corridor, are not the same in all the countries:

Length of freight trains: The length restriction on trains in Sweden is 620 meters but railway operators would rather have longer trains and then use two locomotives if necessary. Distribution of locomotives within the long trains will lead to much more flexibility as trains can be coupled and decoupled depending on need.

From Germany to Denmark today trains of 800 meters are possible. When crossing the Brenner Pass southbound, the maximum is 1.560 tonnes and 540 meters length. When going northbound the maximum is 1.200 tonnes and 450 meters.

A standardized length of freight trains is a future vision.

Side tracks: A standardized train length, which should be greater than 1000m requires side tracks with adequate length.

Tunnel profiles: Different tunnel profiles on RFC noticeable limit the rail freight transport. *Standardized sections are therefore a future vision.*

Axle load: Depending on the type of freight increased axle loads will increase the effectiveness of rail freight transport and will decrease cost and environmental impact. The improvement of related corridors or sections of corridors and freight cars for 25t or higher axle loads will support seamless transport and reduce transportation costs noticeable.

Standardized max. axle load on RFC are therefore a future vision.

Signalling systems: Having a fully harmonised ERTMS system throughout Europe within the next years would be a huge advantage.

intermodal freight terminals come into play as important exit and entry points for the corridor: Typically, road transport covers transport within shorter distances, while rail transport is is most suitable for long-distance transport. This means that road transport logically could be suitable for the transport to and from the corridor, while the (longer) transport along the corridor to the extent possible should be done by rail (if relevant inland waterways along the corridor existed, they also would be relevant). In this connection, the existence of competitive intermodal freight terminals that at the same time provide free and equal access for stakeholders across the affected modes of transport (chosen terminals here: rail and road terminals (RRT)) is important

The improvement of the above points may lead to a more sustainable ”green” transport system. The establishment of a fully harmonised European transport network is the basis for a possible development of multimodal transport of goods across Europe taking into account economic efficiency and respect for the environment.

The RFC1 expects the following improvements by 2030

- Reliability: +26%
- Capacity: +52%
- Time: -20%
- Infrastructure manager’s costs: - 10%-15%.

- Reduced maintenance costs: with ERTMS level 2, trackside signalling is no longer required, which considerably reduces maintenance costs
- Minimum requirements axle load of 22.5 t, a line speed of 100 km/h, a train length of 740 m).
- The complete deployment of ERTMS, to enhance cross-border interoperability and to set up a single Europe-wide standard for train control and command systems;
- The migration to a 1435 mm nominal track gauge;
- The reduction of the noise and vibration impacts. This objective should be achieved through measures for rolling stock, infrastructure characteristics and noise protection barriers;
- The implementation of seamless transport beyond national borders, by increasing the interoperability between national networks;
- The safety of level crossings, ensuring reliability of the network on exposed sections;
- The interconnection between railway transport and maritime or inland ports infrastructures. Equipment for the last railway mile on inland terminals that should be able to host 740m electrified trains.
- Long and medium distance by rail and waterway
- Short distance and distribution by road
- Priority of freight and passenger transport at same level
- RRT and inland ports amongst the corridor for a good coverage, a good catchment area and subsequently a good modal share of Rail and IWW

Increase safety on the corridor

Related KPI's: ERTMS implementation, parking areas

Improve level of service for longer distance links by increasing interoperability and harmonization

Related KPI's: ERTMS implementation, Track Gauge (1435mm), IWW and rail gauges, electrification, PaP (Pre-arranged train Paths)

Improve level of service for longer distance through speed increase

Related KPI : Rail maximum speed

Contribute to reducing environmental hindrance and climate change through extended access to clean fuel at core nodes

Related KPI : availability of clean fuels/energy

Contribute to reducing environmental hindrance and climate change by increasing modal shares of rail and IWW

Related KPI: modal share

TABLE 2-KPIS FOR RHINE ALPINE CORRIDOR; SOURCE [14]

	KPI	Type	Status	Objective 2030	Objective 2050
Rail	Electrification	Passenger/Freight	100%	100%	
	ERTMS	Passenger/Freight	12.3%	100%	
	Line speed	Passenger/Freight	92.5%	100%	
	Axle load	Freight	97%	100%	
	Train length	Freight	25.6%	100%	
IWW	CEMT class IV	Freight	100%		
	Length	Freight	100%		
	Beam	Freight	100%		
	Draught	Freight	69%		
	Height (min 5.25)	Freight	95%		
	RIS implementation	Freight	98%		
Road	Express road or motorway	Passenger/Freight	98.6%	100%	
	Parking areas every 100km	Passenger/Freight	100%	100%	
	Availability of clean fuels	Passenger/Freight	84.3%	100%	
	Interoperability of tolling systems	Freight	68.9%	100%	
Airport	Connection to rail network	Passenger/Freight	38%		100%
	Availability of clean fuels	Passenger/Freight	N/A	100%	
Seaport	Rail connection	Freight	100%		
	Waterway gauge IV connection	Freight	86%		
	Availability of clean fuels	Freight	N/A		
Inland port	Class IV connection	Freight	100%		
	Capacity	Freight	N/A		
RRT	Capacity	Freight	N/A		
Multi-modality	Modal share of rail and IWW (cross-border)	Freight	66%		
	Modal share of rail (cross-border)	Passenger	9%		
	Pre-arranged train paths on the corridor (2015)	Freight	48/day		
Impl. plan	Core project implementation	Passenger/Freight	0%	100%	
	Comprehensive projects implementation	Passenger/Freight	0%		100%

Source: Stratec

Deployment of ERTMS/Signalling, which is one of the requirements of the regulation and a common standard to enhance cross-border interoperability, increase capacity, enhance safety, allow higher speeds, etc. It includes:

o European Train Control System (ETCS), a signalling, control and train protection system designed to replace the many incompatible safety systems currently used by European railways, especially on high-speed lines; and

- GSM-R, the GSM mobile communications standard for railway operations

- Measures concerning passenger lines only, to
    - Prepare rail line for high speed trains
    - Remove missing links from/to well developed sections/lines
- New construction
    - New construction of rail tracks, e.g. to remove bottlenecks due to high gradients, missing links (e.g. interconnections to ports, airports), etc.
    - New construction of tunnels
- Noise and vibration reduction, can be achieved by measures concerning
    - Rolling stock (at the source): new rolling stock with low-noise brakes, retrofitting existing rolling stock with low-noise brakes, wheel-absorbers
    - Infrastructure characteristics: track maintenance for the surface of the rail (rail grinding), track absorbers
    - Noise protection barriers: protection walls, soundproof windows at affected households, facade insulation
- Removal of level crossings, for reasons of safety, punctuality and capacity

Upgrade of existing lines, in order to remove capacity bottlenecks and thus increase the overall capacity; to avoid high gradients, mitigate profile limitations (e.g. upgrade to P400), allow high-speed trains, heavy freight trains (up to axle load of 22.5 t) or long freight trains (length of up to 740 m, as required by the TEN-T regulation), shorten transit times; by e.g.:

- o Rehabilitation of railway lines: railway tracks, railway sleepers, points, electrification, electricity poles, bridges and tunnels, crushed rock, etc.
- o Building of additional tracks to existing ones, for e.g. the use as passing tracks, opposite tracks, etc.

Upgrade of nodes, shunting yards and junctions, in order to remove capacity bottlenecks, maximum train length limitations, etc.

- o Rehabilitation of nodes, shunting yards: tracks, points, railway sleepers, rail brakes, upgrade of hump technology / train formation systems, signals
- o Building of additional tracks: passing tracks, sidings

A lot of issues, bottlenecks objectives and visions are out of the scope of C4R

5.1 Adaptable Railway

An adaptable railway is both flexible and extensible so that, with modest and incremental interventions, rail services can be modified to fit a range of future scenarios – including long-term service-levels and ability to integrate new technology developments. The scenarios include changes in the transport market, modal shift and external demands (such as legislation on greenhouse gas emissions). In building an adaptable railway, innovations and processes will need to be phased into existing railway systems in a sustainable way from engineering and operations viewpoints.

AND

An *adaptable* railway is modular and has well-defined (standardised, open) interfaces and standards for interoperability, so that the railway system can respond rapidly to changes in the pattern of demand – such as providing additional trains to cater for surges in demand generated by exogenous factors (e.g. major sporting events). Improved and innovative construction techniques with less complexity (e. g. of the interfaces between railway sub-systems) and high standardisation that reduce costs and disruptions to users.

5.2 Affordable Railway

An *affordable* railway is the *mode of choice* for investors (public and private) and users (passengers and freight), particularly for medium and long-distance travel. The *affordable* railway:

- Is not just about lowest initial cost, but the total cost of procuring, maintaining and operating the railway based on improved understanding of whole-life, whole-system issues such that lifetime benefits exceed lifetime costs.
- Optimises CAPEX and OPEX (operational expenditure) costs – which are transparent and predictable.
- Is energy efficient and minimises its impact on the environment.
- Delivers lowest Life Cycle Cost while achieving increased reliability, availability, maintainability, safety and quality of the railway system (RAMS performance).
- Meets passenger and freight capacity requirements.
- Minimises barriers to entry and provides effective access to the rail industry.
- Is competitive with other modes for passengers and freight.
- Tries to use innovation to reduce the costs.

5.3 Automated Railway

An *automated* railway is one whose infrastructure and rolling stock are operated and maintained by machines to a degree where the intelligence, speed and scale of operations are no longer correlated with the availability, capacity or capability of human resources. That is, the railway is capable of operating efficiently and effectively without human intervention under normal and (most) degraded service conditions. Automation will cover various aspects such as:

- Construction and renewal
- Monitoring and maintenance
- Operations
- Communications
- Ticketing and pricing
- Inter-modal transfer of passengers and freight

5.4 Resilient Railway

A *resilient* railway is robust, thereby minimising the incidence of infrastructure, rolling stock and operational failures that affect services. Furthermore, a *resilient* railway is one which by design (e.g. of operations, maintenance processes, logistics, tools, equipment) is capable of recovering quickly from perturbations to normal service e.g. as a result of short-term internal events (such as the failure of rail infrastructure) or external events (such as extreme weather conditions, and vandalism).

5.5 High Capacity Railway

A *high capacity* railway is one which has virtually no constraints (bottlenecks) on its operation. A *high capacity* railway can accommodate projected passenger and freight demands spread unevenly through the day (e.g. high flows during peak hours and lower flows at other times optimally), whilst meeting customer requirements in terms of defined service levels (such as, reliability, journey time and frequency of service) in an affordable manner.

A high-capacity railway will tolerate interventions from inspection, maintenance and enhancement with minimal impact on the availability of the transport infrastructure network and enable a move towards the achievement of 100% planned availability (perhaps a 'forever open railway (24 hours/7 days a week)' depending on demands).

High capacity is addressed by rolling stock, operations, infrastructure and railway assets.

5.6 Visions

This section summarizes the unsorted visions with respect to Operation(O), Infrastructure(I), System(S), Passenger(P), Freight(F) and Terminal(T). The

- Cross-border interoperability across Europe through the creation of a single standard for railway signalling (O,)
- Unrestricted cross boarder transport on rail (O, S, L)
- Modular infrastructure which is adaptable to further requirements (I)
- Design and construction of rail infrastructure with standardized interfaces (I)
- Upgradable command and control systems on corridors for high capacity (O, IT)
- Pre-arrange able train paths (O)
- Fixed slots for maintenance (S)
- Adaptable maintenance strategies (S)
- Seamless links to other transport modes (F, O, T)
- No catenary – power supply by conductor rails and fuel cells
- Seamless links to other transport modes (F, O, T)
- High speed freight trains (F, O)
- Each 15 minutes runs a passenger train on more than 50 % of the network (P, O, S)
- Long trains with up to 1400 m with distributed locomotives (F, O)
- High axle loads (F,I)
- Special container transport on high speed passenger trains (plug and play) (P, F)
- One information network for all transport modes (IT)
- "Silent" trains / railway system (P,F,I)
- reduction in transport-related greenhouse gas emissions (P,F,I,O)
- a modal shift of freight from road to rail and/or waterways (F, T)
- a modal shift of medium-distance passenger travel from road to rail (FT)
- expansion of the European high speed rail network (I,S)
- the completion of the TEN-T core network - including rail links to core airports and core seaports (I, S)
- implementation of ERTMS (S, I, F, P, O)

- cross-border interoperability across Europe through the creation of a single standard for railway signalling (S, I, F, P, O)
- a smart, green and integrated transport network (S, I, F, P, O)
- resource-efficient transport (O,F,P)
- better mobility
- less congestion
- more safety and security (I,O,V)
- smart, cost-effective, high capacity, user-friendly rail infrastructure (I)
- intelligent mobility management (IT, O)
- Enhanced unique energy management (I, V)
- Doubled railway network capacity by 2050 (I, P, F)
- Open data models (S, IT)
- Reduction of CO_2 by 50% (I, F, P)
- Exact length of freight train is known (F,IT)
- Known parameter of infrastructure assets(I,IT)

6 Milestones with respect to project targets

The following itemization summarizes milestone with respect to project targets.

- new generation of infrastructure
    - improved for 25t axle load
    - improved for long trains
    - increased reliability and availability
    - Slab track or improved ballasted track
    - Improved S&Cs
    - Monitoring of critical assets to know about the state
    - Predictive maintenance
    - Availability to operate long freight trains
- New generation of rail vehicles
    - Automatic couplers
    - Low noise breaking system
    - 25t axle load
    - Long trains with distributed locomotives
- Improvement of 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.
- Updating the legal and structural legislation in line with EU legislation for regulation of rail transport activities.
- Improved operation for fast recovery after disturbance

- System and Standardization
    - Gauge
    - Power supply
    - Train control system
    - Seamless border crossing
    - New class of container for high-speed passenger trains

The innovations described below demonstrates, that the targets of C4R are in line with the visions and milestones.

SP1

1.1 New concepts of track based on modular slab track embedding elements for power, remote condition monitoring, signalling and communications
1.2 New track designs and specifications for very high speed trains (>350km/h)
1.3 New concepts for switches and crossings design based on failure modes analysis
1.4 New designs for switches resilient to extreme weather conditions
1.5 Optimised S&C sensor strategies

SP2

2.1 Innovations in Trains/Wagons – optimised length, speed, performance, central/automatic coupler, EP/electronic braking, electrification, automation, weight
2.2 Innovations in Freight Operation – wagon shunting, intelligence for vehicles in terminals, terminal operation

SP3

3.1 Ubiquitous data architecture and automated data exchange for railway operations
3.2 Models and simulations to evaluate enhanced capacity (infrastructure and operation)
3.3 Optimal strategies to manage major disturbances

SP4

4.1 New concepts and technologies for using advanced monitoring in embankments, bridges, different track types, switches etc.
4.2 Sensor types
4.3 Energy harvesting
4.4 Communication and data integration technologies

7 Conclusions

The SWOT and bottleneck analysis have shown that the railway system need improvement and visionary to fulfil future requirements and to compete against the road and air. Some of these changes will require huge investments on both sides infrastructure and rolling stock and a new thinking. The analyses carried out in task 5.1.2 clearly point out the issues of the rail freight as the whole and on specific corridors. But lot of these issues are out of the scope of C4R.

The results of C4R are providing a more reliable infrastructure in case of optimized track and S&C construction, which is necessary to increase the capacity. Considering the bottlenecks on the corridors and the necessary migration of new systems the installation of such improvement strongly depends on the local boundaries.

The improvement of vehicle like longer trains or higher axle loads which are pointed out in SP2 directly impact the infrastructure. It is very important to understand, that the related infrastructure improvements should be applied on the whole corridor.

The following aspects are very important to increase the rail freight and to meet the demands which can be found in several documents like white paper of EC.

New generation of infrastructure

- Improved S&C's
- Improved track, slab track or/and ballasted track
- improved for 25t axle load for whole corridor or related sections
- increased reliability and availability
- improved for long trains
- Monitoring of critical assets to know about the state and to support predictive maintenance
- Providing alternative routes

New generation of rail vehicles

- Automatic couplers
- Low noise breaking system
- 25t axle load
- Long trains with distributed locomotives

Improved operation for fast recovery after disturbance

System and Standardization

- Gauge
- Power supply
- Train control system
- Seamless border crossing
- New class of container for high-speed passenger trains

Even if C4R covers only partial aspects of the vision and milestones the project results will be a step forward to a more competitive railway system.

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