Capacity for Rail

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

Catalogue Rail Freight System of the Future (Intermediate)

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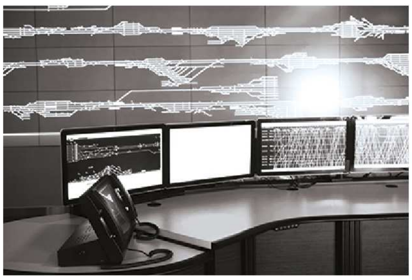




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Foreword

This report is produced for a Work Package 24 under Sub-Project 2 Freight Operations of Capacity4Rail part-funded by the EU (Grant Agreement no. 605650). This report titled "D24.1 Catalogue: Rail Freight System of the Future (Intermediate)" has been contributed by a team consisting of the following organizations and persons:

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To conduct the research, the team held a number of physical and telecom/online meetings (listed in annex II) up to September 2016 when the report was finalized.

As WP24 Leader, UNEW, has been the team Leader for this deliverables and would like to thank all partners for wholehearted support in producing this report. The work has been very interesting with many fruitful discussions. We wish to thank all members of the project team and those who have made other contributions for their excellent cooperation.

Dewan Islam

Newcastle University, UK 20 September 2016

Executive Summary

The EU Transport White Paper 2011 set an ambitious vision of achieving a long-term competitive and sustainable transport system with the following goals:

- 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient, green freight corridors.
- By 2050, a European high-speed rail network should be completed. Triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States. By 2050, the majority of medium-distance passenger transport should go by rail.

Keeping these goals in mind, in this research, C4R attempts to report a comprehensive and integrated rail freight system consisting of, among others, four key areas: network, vehicle, terminal and technical and operational aspects. C4R aimed to study and design new concepts for a modern, fully integrated rail freight system, which meets the requirements of 2030/2050. C4R foresees the following changes necessary to achieve the above mentioned EC goals.

Potential network improvements to increase capacity includes;

- Increase in train length (in line with TEN-T Guidance)
- Increase in axle (Europe wide, e.g. 22.5 tonnes) and meter load
- Increase in average speed (>100km/hour operational, not only theoretical speed)
- Increase in loading gauge

Potential vehicle improvements include;

- Wagon design which can mix 45ft containers and increase the total number of units.
- EP brakes, to generate better train maneuverability
- End of train device to reduce the duration of safety checks prior to departure

Potential terminal improvements include

- For Rail-Road, Rail-Sea and Rail-Rail, operational and technical measures have been identified to achieve both an incremental (2030) and system change (2050).

Potential improvements in operations include;

Short-term measures which aim to use existing infrastructure and vehicles better without major investment;

- Load more freight on existing wagons by using a higher loading gauge.
- Operate heavier trains by utilising the tractive power of modern locomotives
- Standardise braking rules and tables that make better use of possible performance
- Operate faster freight trains (in the range of 100 to 120 km/h) to obtain more train paths
- Operate longer trains on the major TEN-T corridors and at special times where possible
- Establish a freight database for groupage to utilise capacity better
- Secure sufficient quality in international freight corridors

In the **medium and long term** there are further measures that require closer analysis and sometimes investment:

- Secure capacity in international freight corridors
- Optimisation of wagons for different customers' needs with larger loading gauges and higher axle loads
- Heavier trains with locomotives that have higher static adhesive weight
- Longer trains responding to market needs on special freight routes
- Lighter wagons with lower tare and higher payload
- Introduce incentives for track-friendly running gear and for better brakes and improved braking performance
- Introduce automatic couplers to reduce shunting costs and widen the market

Alongside meeting the above mentioned improvements, C4R recommends the following steps:

- Freight train operators will conduct a combination of 'terminal-to-terminal' and 'door-to-door' service operations;
- They must build partnerships with other modal (e.g. road) operators and freight forwarders or 3PLs to include all types of customers including SMEs and customers of non-rail (low density high value) cargo.
- They need to make use of consolidation centres that facilitate bundling of cargoes, in particular for urban areas which are location of majority of the European freight transport customers.
- Introduce an on-line information system with the actual rail freight connections and terminals with connecting services.

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Abbreviations and acronyms

CO2	Carbon Dioxide
EC	European Commission
EOT	End of train device
ERTMS	European Rail Traffic Management System
ETA	Estimated Time of Arrival
EU	European Union
EU15	The 15 first member states of the EU in Western Europe
EU12	The 12 new member states of the EU in Eastern Europe
EU27	The 27 member states of the EU
GHG	Greenhouse Gas
GPS	Global Positioning System
HSR	High Speed Rail
IM	Infrastructure Manager
KW	Kilowatt
KWH	Kilowatt hours
kN	Kilonewton
LDHV	Low Density High Value Goods
RFID	Radio-frequency identification
RFC	Rail Freight Corridors
RNE	Rail Net Europe
TEN-T	Trans-European Transport Networks
TEU	Twenty-foot Equivalent Unit
SME	small and medium size enterprise

1 Introduction

1.1 Background

CAPACITY4RAIL aims to answer the question "How to obtain an affordable, adaptable, automated, resilient and high-capacity railway; for 2020, 2030 and 2050?" The current research takes a comprehensive system approach and efficiency will remain a key word that can largely be achieved by ensuring a high level of capacity and availability of the network at a low cost, the so called 'do more with less' approach.

The European Commission (EC) Transport White Paper 2011 entitled "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system" has set an ambitious vision of a long-term competitive and sustainable transport system with the aim of attaining goals set for reducing the transport sector's emissions. Rail transport related goals stipulated in the White Paper are:

- 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient, green freight corridors.
- By 2050, a European high-speed rail network should be completed. Triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States. By 2050, the majority of medium-distance passenger transport should go by rail.

Keeping these goals in mind, in this research, C4R will try to report a comprehensive and integrated rail freight system consisting of, among others, four key areas: vehicle, network, terminal and technical and operational aspects.

Rail freight's main business activities were traditionally bulk traffic of cereals, refined oil products, sugar, fertilizer and building materials. However, as the market changed towards goods transported predominantly in containers which required a door-to-door reliable service, rail was unable to capture this new type of cargo. This segment of cargo is continuously increasing and large volumes are captured by the road sector, which offers services with a high level of quality, reliability and flexibility. Fierce competition from road has challenged and had negative affects particularly on the single wagon load (SWL) segment of rail traffic. SWL traffic needs a comprehensive network to serve customers with minimum flexibility supported by very heavy fixed costs. As a result SWL traffic volume is decreasing and this segment of rail freight business has generated heavy losses in the incumbent accounts during the last fifteen years.

The question, what is the solution to this challenging business environment? Is frequently posed. Currently the EU consists of 28 Member States and most of them have an average transport distance across each state of below 300 km. Research by academics and practitioners has identified that rail freight services become effective and commercially viable over 300km distances. This notion is also supported by the EU Transport White Paper 2011. One solution is to lengthen the trunk travel beyond the borders, although the national rail networks were built to serve national market needs. Another solution is to develop containerised intermodal transport services, a segment of rail traffic which has developed very rapidly over the last few decades and forecasts suggests that this trend will continue. However the transhipment, delivery and collection on short to medium distances remains an issue, as road transport offers a direct option. To address this, appropriate transhipment techniques and well thought out terminal locations are key. Also the development of a trans-European transport (TEN-T) network for intermodal transport connected with regional transport will be vital. Along this line, a number of detailed studies, for example, (European Commission, 2014a, 2014b, 2014c, 2014d) have been conducted to identify the specifics of technical and operational development needs.

During the last two decades, developments for intercity high speed passenger trains have been undertaken, but no large infrastructure developments for freight trains which could increase rail freight service reliability and competitiveness have occurred. Confronted by the slot competition of faster passenger trains taking priority, freight train reliability and service quality has decreased.

The European Union promoted the creation of a fully interoperable European rail network, through the production of different Directives and Railway Packages, in order to overcome the various barriers existing at each border, in terms of infrastructure, operations, and safety constraints. The establishment of a safe, modern integrated railway network is the EU's ultimate priority. In a competitive market, railways must become more competitive and offer reliable high-quality, end-to-end services without being restricted by national borders.

The European Railway Agency (ERA) was set up to help create an integrated railway area by reinforcing safety and interoperability. The Agency also acts as the system authority for the European Rail Traffic Management System (ERTMS) project, which has been set up to create unique signalling standards throughout Europe. Information on technology and automation technology are big factors of progress. The European Railway Agency is trying to harmonise the train management system through the implementation of ERTMS, to implement a complete sets TSIs, to impose common safety methods. The ultimate objective is to have a common set of rules to homologate all the rail freight rolling stock able to run safely on an infrastructure complying with the TSIs.

To face the new and ever increasing challenges, rail freight must be innovative to gain competitiveness, reliability, capacity and flexibility. Researchers throughout many European projects under the FP7 have tried to improve several parameters in particular the main key performance indicators (KPIs). The main driver is to change the marketing strategy from 'supply' to 'demand' oriented service meaning that the freight operators have to focus main customer demands and requirements and apply all possible approach and technique to meet those requirements.

As part of the global logistics system, freight and logistics customers may serve several regions in different Member States in Europe. Therefore it is necessary to have a fully integrated network and an innovative approach must be implemented to increase service reliability, for instance, with predictive maintenance of wagons and networks as well as responding to variable and unpredicted demand by extending the capacity (e.g. train length). Improving all transhipment points (rail-rail, rail-road, rail-barge, rail –sea and vice a versa) to an automated process is extremely important. The rail freight system will not function properly if it is not supported by a comprehensive information system managing the entire information and cargo flows, ensuring smooth connections at transhipments points, updating regularly the information on the estimated time of arrival at the terminals or correspondence points, monitoring the status of the equipment and of the cargo – this implies a dynamic transmission of information with a clear positioning of the mobile and a capacity of updating the calculation of new estimated time of arrival (ETA) in case of incidents. The new integrated rail freight system must address the cost element that will always remain a top priority for the customer and will require higher asset utilisation and automation including for train movements on secondary lines.

1.2 OBJECTIVES

The objectives of WP24 are as follows:

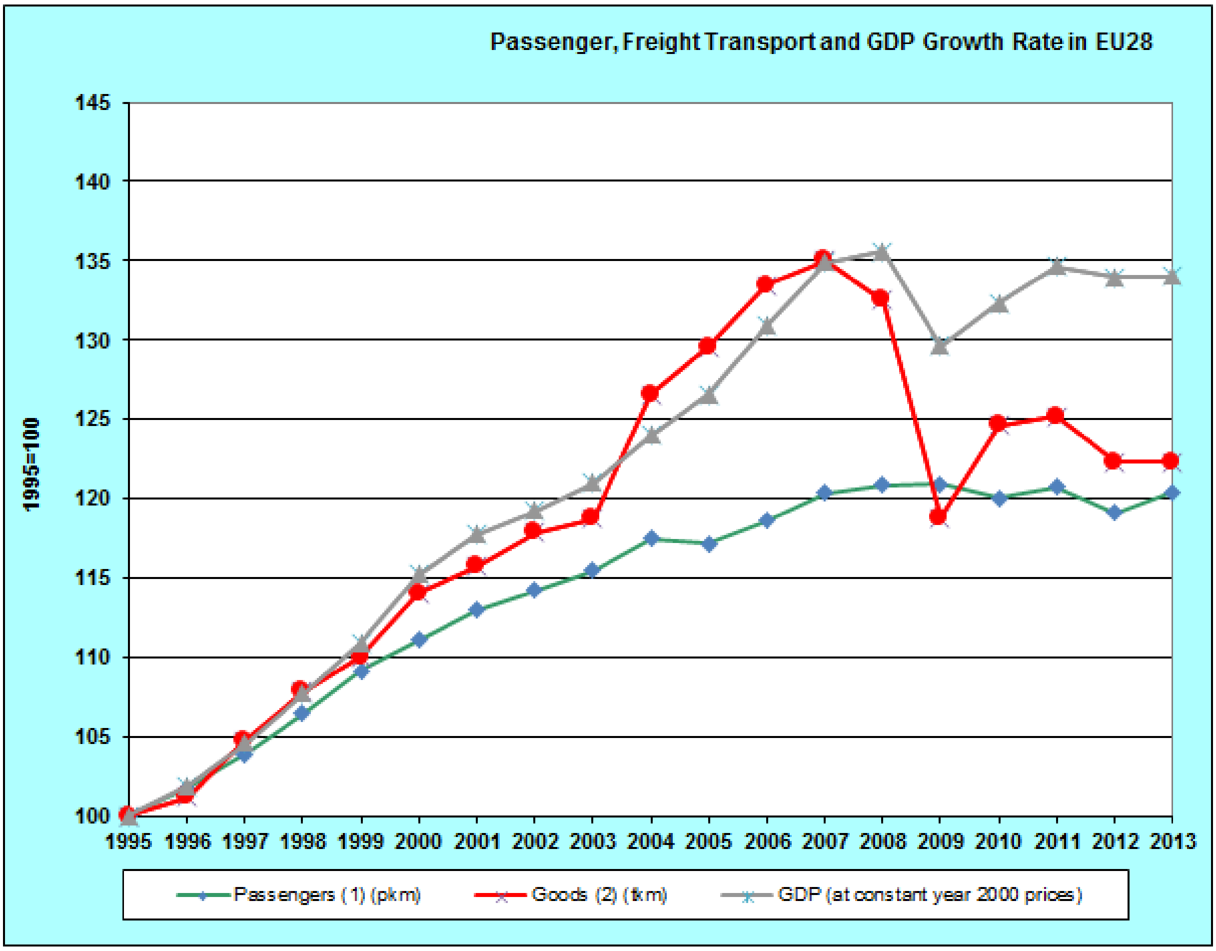
- To study and design new concepts for network-based services for fully integrated rail freight systems to meet the requirements of 2030/2050;
- To assess the performance of newly designed fully integrated rail freight systems using a modelling framework;
- To analyse the potential of newly designed, fully integrated rail freight systems and understand the expected market up take levels;
- To produce a catalogue on rail freight systems to contribute to the Commission’s goals for 2030 and 2050; and
- To suggest standards for fully integrated rail freight systems.

As the first task of the WP24, this research will study and design new concepts for a modern, fully integrated rail freight system to provide efficient network –based services based on principles for seamless logistics and hence meet the requirements of 2030/2050. More specifically findings and conceptual system designs achieved so far as a result of EU collaborative rail freight research efforts will be integrated to build a new interoperable system for rail freight incorporating a new generation rail freight vehicles, seamless freight transhipment as well as intelligent, interoperable rail networks allowing very high speed, characterised by climate-resilience, shorter downtime and low maintenance cost.

1.3 European Freight Transport

For EU28, GDP grew at 1.6% over the period of 1995-2013 whereas the passenger and freight transport growth were 1.0% and 1.1% respectively. The total inland freight transport has increased from 1914 billion tkm to 2391 billion tkm, a 1.2% annual growth, during the same period.

Figure 1.1 GDP and freight growth for EU28



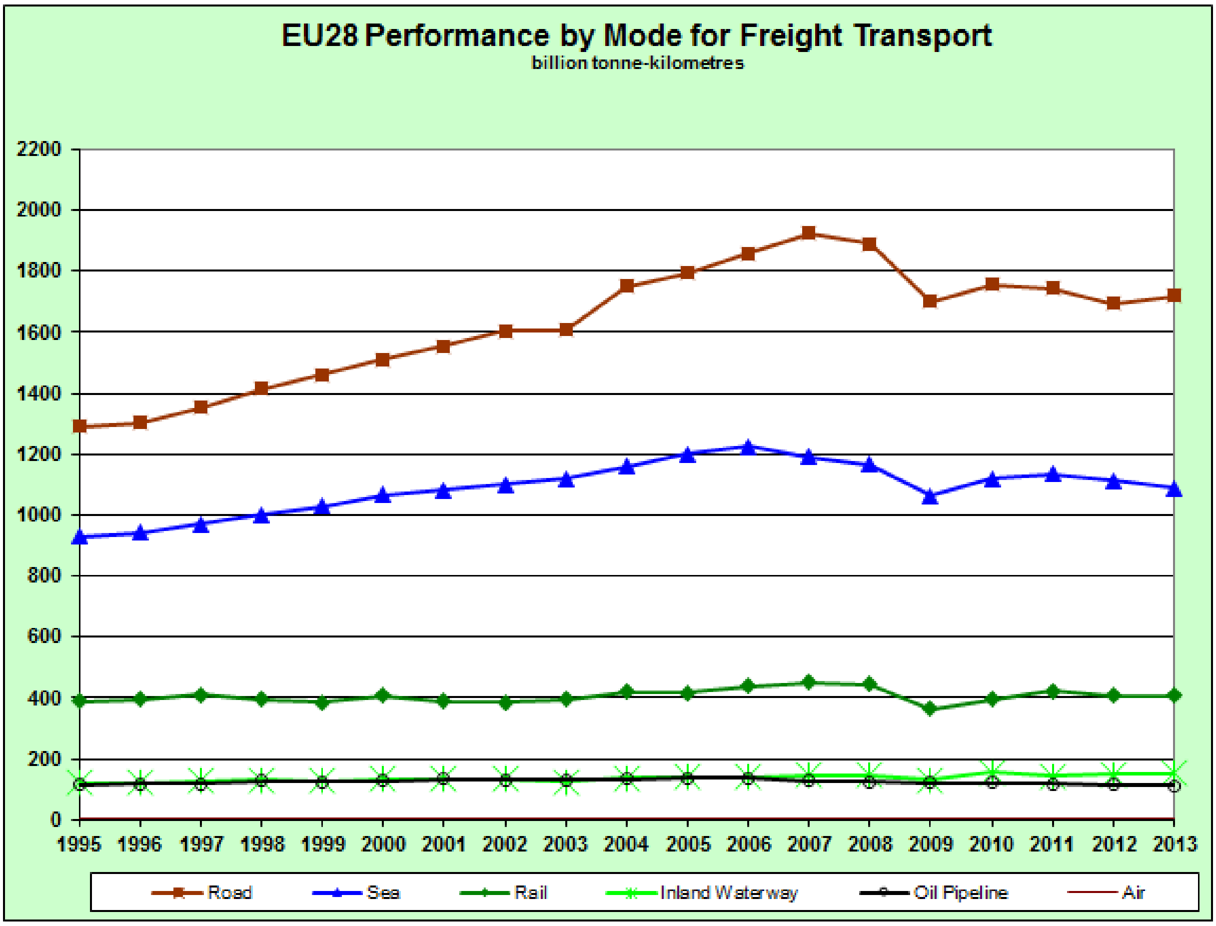
Source: EU Statistical pocketbook 2015 (EC, 2016)

In 2013 total goods transport activities in the EU-28 are estimated to amount to 3 481 billion tkm (increased from 2848 billion tkm in 1995, a 1.1% annual growth). Road transport accounted for 49.4% (increased from 45.3% in 1995) of this total, rail for 11.7% (decreased from 13.6% in 1995), inland waterways for 4.4% (increased from 4.3% in 1995) and oil pipelines for 3.2%. Intra-EU maritime transport was the second most important mode with a share of 31.3% (slightly decreased from 32.7% in 1995) while intra-EU air transport only accounted for 0.1% of the total.

The total rail freight transport volume in billion tkm in EU28, EU15 and EU13 have decreased (from 551.1 billion tkm to 406.5 billion tkm in EU28; from 282.5 billion tkm to 263.8 billion tkm in EU15 and 268.6 billion tkm to 142.7 billion tkm in EU13) between 1970 and 2013 with some ups and downs in different years. After decreasing until 1995, there is an increasing trend, with of course ups and downs, in all of these three blocks until 2013. Compared to EU15, the decrease in EU13 countries is severe.

One finds that most of the increase freight volume has been handled by road transportation so the market share for road transport whereas the rail freight volume and share have been constant or decreased during the same period. Although one can say that the rail market share has stabilized and slightly increased since 1995.

Figure 1.2 Performance of different freight transport modes



Source: EU Statistical pocketbook 2015 (EC, 2016)

1.4 Rail freight market share for different commodities

The most important market segments for rail

In order to estimate the importance to rail of different goods, a *Vocation Indicator* has been introduced that shows the preferential transport mode for each type of goods.

$$I_{road} = \left(\frac{Q_i}{Q_{tot}}\right)_{Road}$$

$$I_{rail} = \left(\frac{Q_i}{Q_{tot}}\right)_{rail}$$

where:

- Q_i is the transported amount of a considered goods type;
- Q_{tot} is the total of all goods categories.

In Europe the highest vocations for rail transport are for the following types of goods, see figure 1.3 and supplement.

- GT02: coal and lignite; crude petroleum and natural gas;
- GT07: coke and refined petroleum products;
- GT08: chemicals, chemical products, man-made fibres; rubber and plastic products; nuclear fuel;
- GT10: basic metals; fabricated metal products, except machinery and equipment;
- GT12: transport equipment;
- GT19: unidentifiable goods: for any reason cannot be identified and therefore cannot be assigned to groups 01-16.

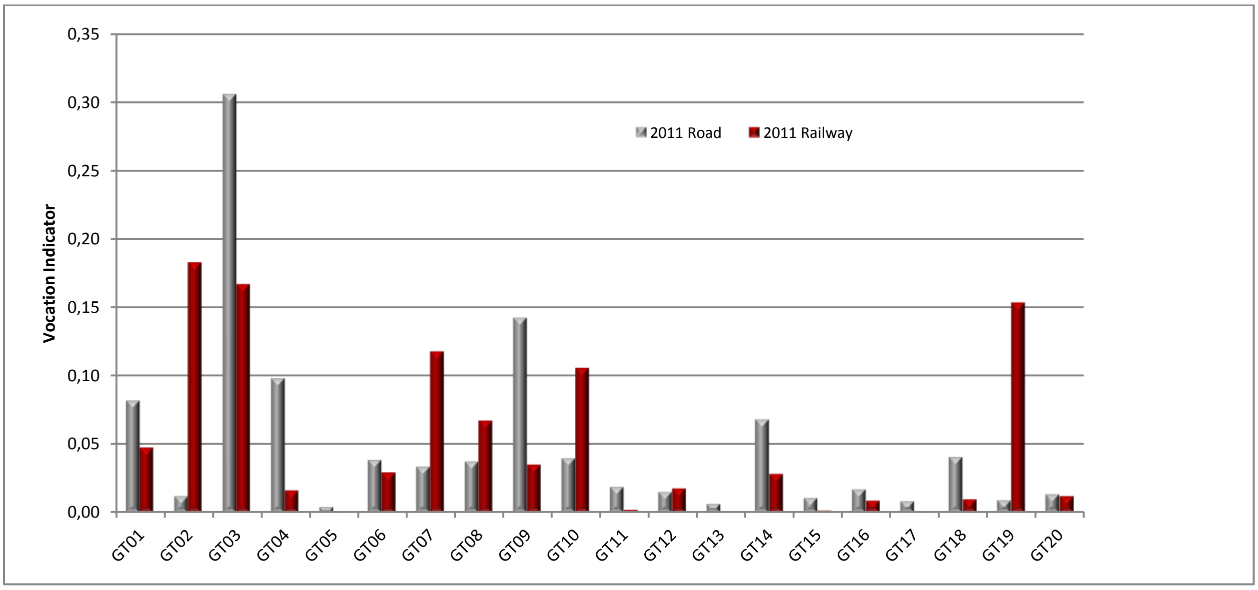


Figure 1.3: Vocation Indicators for road and railway by NST goods typology. The goods categories are explained in the annex. Source: DICEA.

1.5 Forecasts of total demand in the EU and rail's market share

The D-RAIL (2012) project forecasted the future levels of rail freight demand assuming three different scenarios: 1) Reference scenario with no change from the current rail system in infrastructure, policies and other trends; 2) White Paper High Scenario and 3) White Paper Low Scenario. The High and Low Scenarios assumed that a full (50% by 2050) and partial (30% by 2030) modal shift of cargo from road for distances over 300 km to rail will occur according to the targets set by the European Union Transport White Paper (2011).

Figure 1.4 shows the rail freight demand in tonne-km for different EU segments. It can be seen that the total demand is higher for the second version, where the total shift is allocated entirely to rail. There is also a difference in slope regarding the two white paper scenarios. In the Low scenario, the growth rate from 2030-2050 for EU12 is higher than for EU15. However, in the High scenario the slopes are reversed. This shows that in a more realistic scenario, growth in EU12 will be higher, even if there is a shift from road. On the other hand, in a more optimistic scenario, the road shift mainly occurs in EU15, increasing the slope value, see figure 1.4.

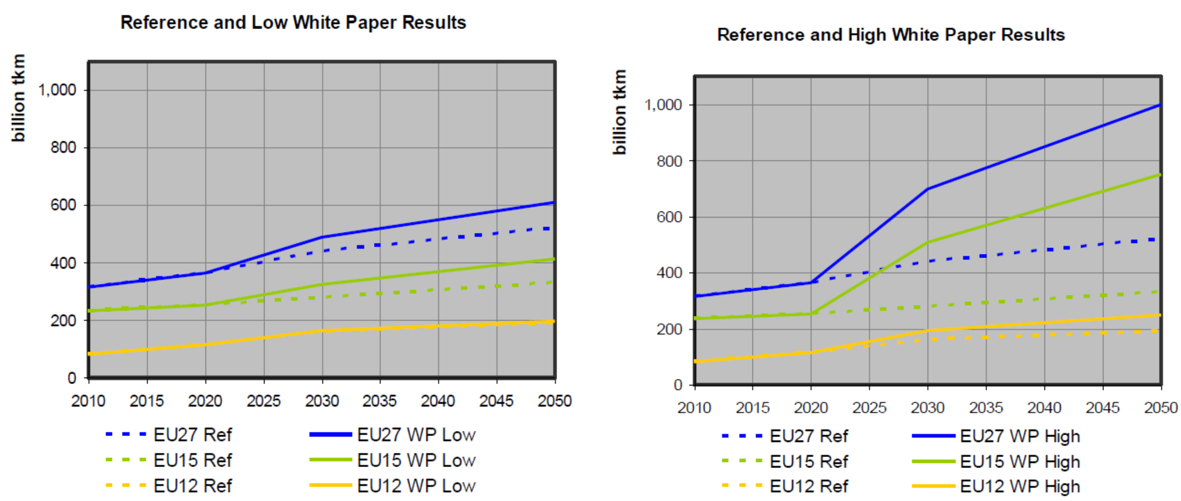


Figure 1.4: Rail demand for EU27, EU15 and EU12 in billions of tonne-km (D-RAIL, 2012 p. 39).

The D-RAIL forecast suggests that the main volume of goods stems from the EU15 countries. It was noted before that the particularity of the White Paper scenarios is to incorporate a percentage of road goods for distances over 300 km, effects on the total demand, and its distribution as depicted below in Figure 1.5. The main flows are for manufacturing materials, transport equipment and coal. The commodities whose share has shrunk are coal (8.3%) and metal waste (3.6%). But the actual demand for these commodities has either remained the same or increased slightly. This indicates that the shift in road demand does not concern these commodities. The main increase is observed for (containerised) transport equipment and foodstuffs, followed by chemicals and agricultural products. Hence, these commodities to a certain extent represent the demand transferred from road to rail.

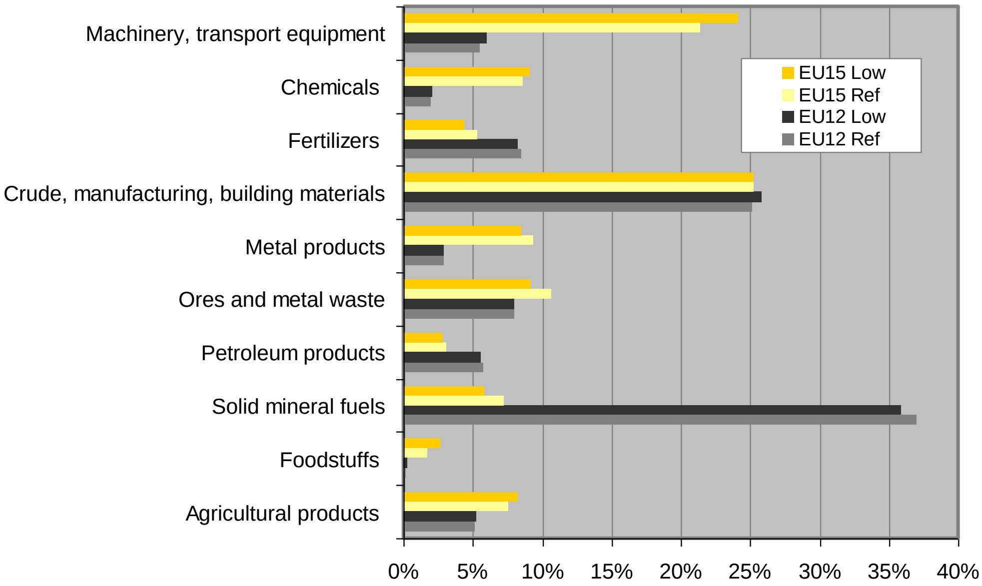


Figure 1.5: Commodities distribution for 2050 for White Paper Low Scenario in tonne-km (D-RAIL, 2012 p. 45).

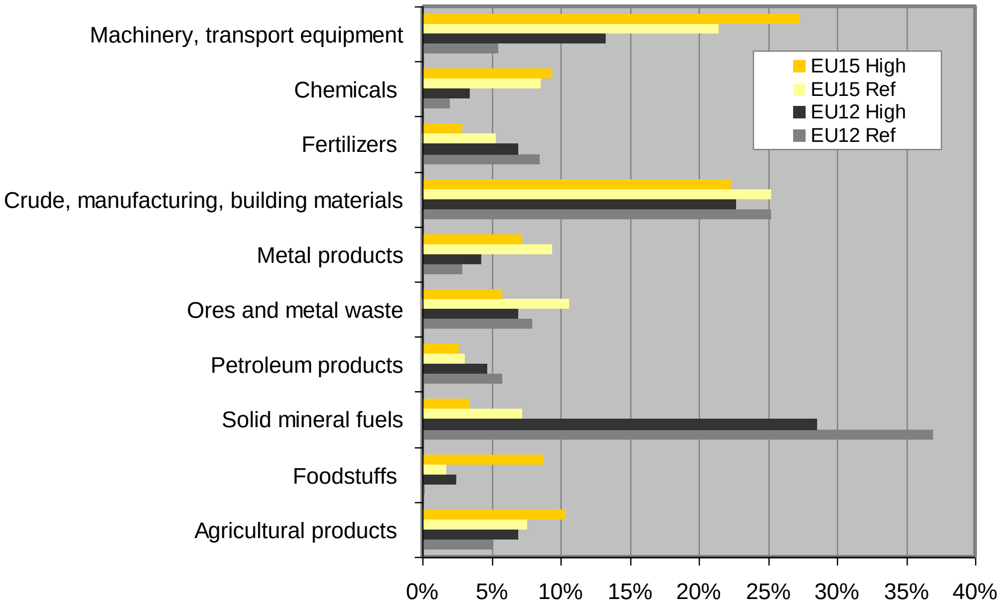


Figure 1.6: Commodities distribution for 2050 for White Paper High Scenario in tonne-km (D-RAIL, 2012 p. 47).

Table 1.1 Rail demand in tonnes and tonne-km

EU27 with some excptions	2010	2020	2030	2050	Increase 2010-2050	Growth per year	Shift from reference 2030	Shift from reference 2050
Rail demand in mtonnes								
Reference	1,040	1,260	1,590	1,902	83%	1.52%	0,000	0,000
Low White paper scenario*	1,040	1,260	1,650	2,067	99%	1.73%	0,060	0,165
High white paper scenario	1,040	1,260	2,307	3,224	210%	2.87%	0,717	1,322
Rail demand in btonne-km								
Reference	316	365	439	521	65%	1.26%	0	0
Low White paper scenario	316	365	488	611	93%	1.66%	49	90
High white paper scenario	316	365	699	1000	216%	2.92%	260	479
Average transport length								
Reference	304	290	276	274	-10%		0	0
Low White paper scenario	304	290	296	296	-3%		20	22
High white paper scenario	304	290	303	310	2%		27	36

*) This figure for tonnes 2030 is wrong in the report and has been estimated from the diagram

Source: Calculated from D-RAIL, 2012 by KTH.

An important observed change is the share between EU15 and EU12. For both the Reference and the Low scenario, the split between the two clusters was 60% to 40%. The High scenario results in a split of 70% (for EU15) to 30% (for EU12). Therefore, the countries that mainly contribute to the modal shift in future demand are within EU15. On the other hand, the EU12 countries do not increase their traffic by more than 24%, with the exception of Slovenia (45%) which is strongly characterised by transit demand.

Table 1.1 illustrates projections from the scenarios. In the Reference and Low scenarios, growth is 65% and 99% from 2010-2050. Growth for the High scenario is more than double, 216%, that in the Reference scenario. The countries that show the highest relative growth are in EU15, with Germany and Italy still maintaining the highest positions. In EU12, the higher flows originate from Poland, the Czech Republic and Romania, representing 60% of the total EU12 demand.

However, the average distance in km by rail decreases in both the Reference and the Low scenario and only shows a slow increase in the High scenario. One explanation is modelling limitations. Otherwise, a shift to rail for distances over 300 km should expect an increase in the average distance.

1.6 Methodology

Literature review is the research methodology applied for this research. The principal working method was gathering facts from scientific papers and relevant reports, investigations and working documents that have already been published or where the results are available. A 'brain storming' session was held on 16 November 2015 to conduct in-depth discussion regarding an integrated rail freight system. An attempt was made to define what is meant by 'fully integrated rail freight system' and it was agreed that a fully integrated rail freight system can be achieved by addressing its four main sub-systems or components in a coherent and complementary way: new generation rail vehicles; intelligent and interoperable rail networks, terminal capable of offering seamless freight transhipment; and operations. It is worth mentioning that the principles for seamless logistics should include pick up (pre-haulage) and delivery service (post-haulage) and the railway undertakings and operators will have to work the road haulage for such door-to-door services.

The rail freight customer requirements are discussed in section 2. The network subsystem is discussed in section 3; the vehicle sub-system is discussed in section 4; and the terminal subsystem is discussed in section 5; the operations is discussed in section 6 followed by a summary and conclusion in section 7.

2 Customer Requirements for different goods segments

2.1 CUSTOMER REQUIREMENTS AND MODE CHOICE

Rail freight transport may not develop in the EU to the extent necessary to be in line with the sustainable development targets fixed by the Commission. Various reasons explain this apprehension. The market has changed from large quantities of bulk being transported by block trains to smaller shipments, more frequently and with a higher value. The development of the European single market, regularly extended to new member states joining the EU, has boosted international traffic but it faces interoperability issues at the borders and it takes a long time to overcome by technical, administrative harmonization and standardization. The decline in freight traffic is associated with a lack of investment in rail infrastructure. It is further aggravated by the priority on high-speed passenger trains lines that affects the reliability of service, a key bottleneck, which means uncertainty about the reliability of ETA impacting supply chains and customers' inventory level. Relatively few freight villages have emerged to support industrialization of rail transport, thus more collaborative approaches are required to counteract the strong competition from efficient road transport. Lack of innovation, delay in introduction of innovation, for example ICT facilitating access to rail have also hindered development. The lack of coordinated urban planning to create powerful industrial clusters strongly suggests that authorities in different countries are not very conscious of the importance of rail freight transport for the future.

Originally developed to capture the domestic market with government owned and operated railway undertakings, the industry has gone through some economic and regulatory reform. However it has not developed the necessary collaborative or integrated approach at European level as a result of a number of factors; for example the multiplicity of actors in the multimodal supply chains which sometimes have opposing interests. This situation coupled with high barriers faced by new entrants has hindered the development of industrialized trans-European services to respond to market needs. Moreover, no modern studies of this market to anticipate its evolution have been introduced on a large scale. Still it is dominated by large incumbents who are more preoccupied by the protection of their market share than introducing new business models to face the changes in demand.

The bundling of various categories of traffic (bulk, wagonload and combined transport), the creation of efficient nodes to face the bottlenecks by optimizing the use of all existing infrastructure, the development of fully interoperable trans-European corridors with powerful governance and a coordination with national infrastructure managers progress too slowly. Overcoming the patchwork of national safety rules through powerful action by the ERA is progressively arriving at an urgent need to increase the pace. A multi-channel distribution strategy and logistics engineering must enter this very conservative rail world. All these elements have hindered the introduction of rail links in supply chains which are as weak as their weakest link.

Generally speaking, rail freight transport becomes favourable for high volume low value (HVLV) cargo such as coal and ores. One important reason for this is that the shippers look for lower transport cost rather than faster and reliable transit times. These types of cargo can also generally use a less-reliable transport service. By contrast, the shippers' requirements for non-traditional cargo, e.g. high value low density (LDHV) cargo, differ significantly. Apart from the transport cost, the transit time is very important for this type of cargo. Some of the goods carried are also time-sensitive and require temperature control, for example fish, fruit and vegetables. SPECTRUM (2012) suggests that a delay in delivery and distribution of goods is a serious weakness in some market segments such as the food retail sector. If these goods are not delivered on time, there is a bigger chance that they cannot be sold at all. A new rail freight service should therefore focus on these issues and be able as a minimum to match the service and product offerings of the road transport sector.

The SPECTRUM study (2012) identified the following most important shipper's requirements for LDHV cargo (in order of importance):

- ***Reliability of service:*** intermodal rail transit time has to be competitive with road. However, consistently and unfailingly reliable transport (i.e. arriving at the agreed time) is for many shippers even more important than the transit time itself. This is especially the case in the automotive industry, which is the industry with the largest share of 'just-in-time' (JIT) and 'just-in-sequence' (JIS) deliveries. The electronics industry (especially end products) is also highly organised with JIT production structures. The critical issue with these types of deliveries is not the speed of the delivery, but the reliability of the transport.
- ***Costs of door-to-door delivery:*** rail transport is often, but not always, more expensive than road transport, especially for relatively short distances. In general, low overall costs can be reached when combining rail volumes in a corridor and more intensive use of the rolling stock and traction assets.
- ***Service availability:*** service availability at the origin point seems to be just only slightly more important than at the destination point.
- ***Safety and security:*** reducing the chance of losses, theft and damage. This is especially important for the transport of high value goods. In general, rail freight transport has a competitive advantage over road transport with regard to safety (less chance of shifting in wagons) and security (less chance of theft).

2.2 Rail products for different markets

Market requirements vary for different commodities and rail has to meet the demand with different products. The demands for some different commodity groups are specified in the form of transport time requirements, frequency and rail's main products in table 2.

For commodities transported between different industries and warehouses, these are normally produced during the day and shipped overnight, preferably with daily departures. In international traffic, however, the daily rhythm is somewhat different. Prices must generally be low because these goods are not normally highly refined. This means that substantial capacity is needed as regards weight or volume. Capacity requirements vary.

For freight transported to the process industry, continuous departures are often more important than overnight transportation. This is high volume system transportation, which means that prices are low. The capacity required is at least as high as for the basic products. On the other hand, precision must also be high.

Distribution shipments of finished goods to warehouses or direct to the consumer can be divided into two groups. One group has the same transportation time requirements as the basic products but demands higher quality, for example in terms of handling, cargo securement, temperature, etc. and has a more disparate structure. The requirement for overnight transport is more precise and often concerns the period between 5 pm and 7 am.

Lastly, there is an express freight market, e.g. for spare parts, where the requirements coincide with those of the passenger trains, i.e. high average speed, high accessibility during most of the day (high frequency of service) and broad geographical coverage of the market. Compared to normal freight transportation, the price levels in this market are relatively high.

The freight transport system can be divided into the following main products with regard to market and production system: Wagonload traffic, Unit trains, Intermodal traffic and High-speed freight trains.

Wagonload traffic

Wagonload traffic is the oldest product and has for a long time been the basis of the railways' freight traffic system. Principally, it meets the base market's need to transport raw materials and semi-manufactures. It comprises the transportation of whole wagons that are loaded and unloaded by the customers at industrial sidings or on team track platforms. Wagonload traffic may consist either of single wagons or groups of wagons. The wagons are often marshalled twice or more during their journey. Where the sender or the recipient has no industrial spur, the goods transported by rail can be reloaded to road haulage. SWL traffic needs a comprehensive network to serve customers with minimum flexibility supported by very heavy fixed costs. As a result SWL traffic volume is decreasing as illustrated in Figure 2.1 This segment of rail freight business has generated heavy losses in the incumbent accounts during the last fifteen years.

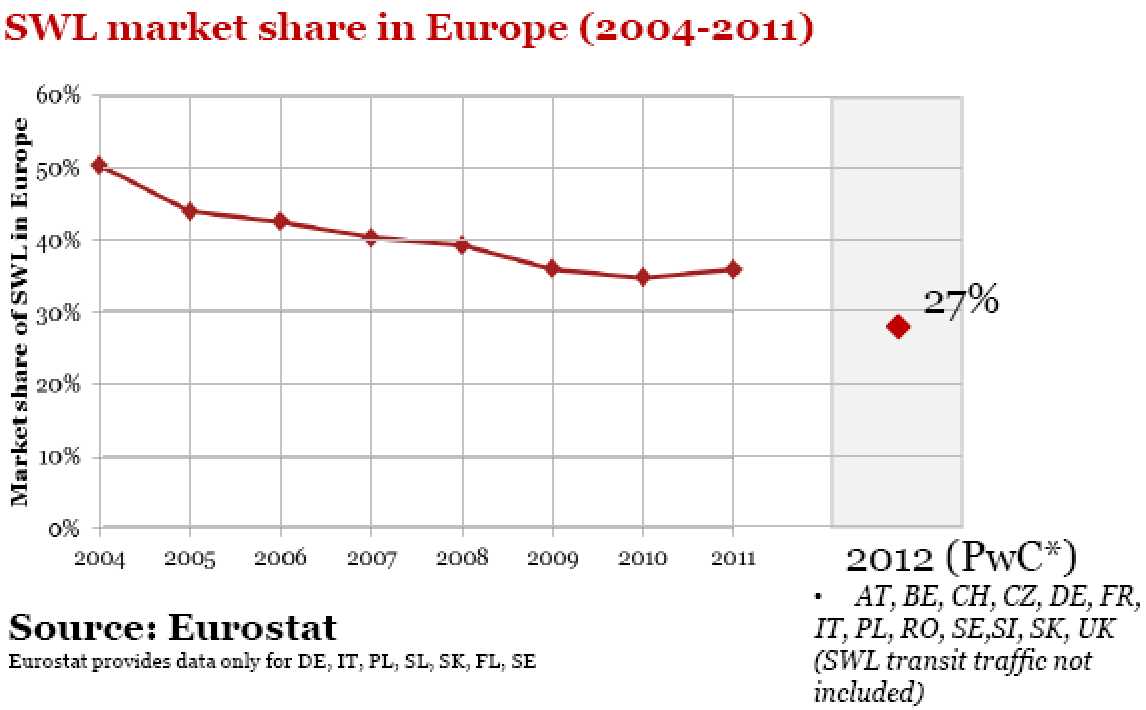


Figure 2.1 SWL Market Share in Europe 2004-2011

Unit trains

Unit trains are freight trains that form part of customised logistics systems where the railway functions as a conveyor belt for industry. Each unit train is operated for a specific customer with dedicated wagons and according to their own timetable. Unit trains use basically the same technologies as wagonload traffic, but unit trains allow the railway's economy of scale to be exploited to the full. Typical loads are iron ore, raw timber, steel, wood chips, peat, oil, and paper.

Intermodal traffic

In intermodal traffic, rail is used for the long-distance haul between the terminals and trucks for the short-distance feeder transport. For easier and faster handling unit loads are used as containers, swap-bodies or semi-trailers are used. The wagons mostly travel directly in separate trains directly between the intermodal terminals. Shipping ISO container traffic to ports and trailer traffic to ferry berths are extensive. Intermodal transportation also means that several small shipments, which form a significant part of total freight movements, can be consolidated.

Express freight

Express freight consists of time-sensitive goods such as post or parcels and small but higher value and possibly time sensitive consignments up to a pallet in size. Transportation is generally overnight with late departures and early arrivals so that collection and sorting can be done at the terminals before departure and sorting and distribution upon arrival. For such traffic, third party logistics service providers play an important part for consolidation. Some trains make scheduled stops along the way for loading and unloading the incoming or outgoing container or palletised traffic.

Development

In Europe general development in recent decades has been that wagonload has decreased and unit trains and inter modal have increased. However, for transport of liquid and solid bulk cargo, there was decrease due to reduction of coal for power plant for electricity production e.g. in France in conjunction with the development of Nuclear energy and transport for steel plants, e.g. recent closure of steel plants in the UK. In some countries, wagonload has been abandoned, and in other countries it has been concentrated to fewer customers and more groups of wagons instead of single wagons. Intermodal has increased, especially to and from ports in line with containerization and increased world trade. Express freight is a marginal product and only exists in some countries e.g. Sweden.

Table 2.1 Different market segments, customer requirements and main rail products. Source KTH.

Market segment	*Time requirement*	*Frequency*	*Rail main product*	*Cooperate with*
Bulk freight - raw materials	less than 24 hours	continous	unit trains	shipping
Basic market - raw materials - semi manufactures	Domestic: 0-1 days International: 1-3 days	daily several/week	wagon load	shipping
Product market - semi manufactures - finished products	over night 17:00-07:00	daily	Inter modal	truck
Service market - mail, parcels - Express freight	over night same day	daily several/day	Express freight train	air cargo truck delivery

3 European Rail Freight System- Corridors & Networks

After decades of effort, it is commonly recognised that the present European rail freight system remains fragmented and differs significantly from county to county. There are differences in regulation, legislation, power supply systems, gauges, ITU´s, etc. etc. that limits the possibilities of optimised efficiency and capacity within the rail freight system. Today trains are generally maximized to 1,500 gross tonnes and a maximum length of 650–750 metres but it is technically possible to use trains hauling 2,000–2,500 tonne and up to 1,000 meters in length. In Europe, train lengths up to 850 meters already do exist and successful experiments have been made up to 1,500 meters long trains in France.

A larger loading gauge is at least as important as a higher axle load/weight per metre and the greatest effect is often obtained by combining the two. In Sweden, a very generous loading profile (C) is already being introduced in most of the network. But the UK, France, Italy, Spain, Portugal, East European countries have less than Gauge C and the first step would be to have in real time the real dynamic clearance profile in absolute coordinates separately which must be respected by the trains with their cargo. On many lines, it has proven to be possible to enlarge the loading gauge by relatively simple means. Even if more complicated measures are needed in some cases, for example in tunnels, the total cost is nonetheless not excessive. It is very important to make the loading gauge rectangular by removing the bevelled corners, which is sometimes simpler and important from a market perspective.

To improve capacity, British Network Rail adopted a strategy in 2004 to guide enhancements of loading gauges and in 2007 the freight route utilisation strategy was published that identified a number of key routes where the loading gauge should be cleared to W10 standard, and where structures are being renewed or new ones built the W12 will be a preferred standard.

A number of intelligent solutions exist both for the planning and operation of trains. Ranging from freight train monitoring and real time information management to tracking and tracing. Examples of real time monitoring solutions include ISR (International Service Reliability), a common tool which can track both empty and loaded wagons across a significant part of Europe and Train Information System (TIS http://tis.rne.eu/), a web based application which delivers real time train data for international passenger and freight services which the Infrastructure manager can then process. Systems for tracking and tracing include; Uniform system for European Intermodal tracking and tracing (Use-IT) to support both the rail undertaking and intermodal customers, allows the tracking of trains and containers in real time over the internet.

There are many kinds of rail freight corridors in Europe; time-table corridors with “one stop shop”, the TEN-T-network, the planned ERTMS corridors, The Rail Net Europe corridors and the New Opera corridors. The aim is to prioritise slots for freight trains in the short term and build a network with high capacity, long trains and high axle load in the future. TEN-T-network, planned ERTMS corridors and Rail Net Europe corridors are discussed below.

3.1 TEN-T NETWORK

The new EU infrastructure policy will put in place a powerful European transport network across 28 Member States to promote growth and competitiveness. It will connect East with West and replace today's transport patchwork with a network that is genuinely European. The core network will be established by 2030.

The new policy establishes, for the first time, a core transport network built on 9 major corridors: 2 north-south corridors, 3 east-west corridors and 4 diagonal corridors. The core network will transform east-west connections, remove bottlenecks, upgrade infrastructure and streamline cross-border transport operations for passengers and businesses throughout the EU. It will improve connections between different modes of transport and contribute to the EU's climate change objectives.

Financing for transport infrastructure will triple over the period 2014-2020 to €26 billion. This EU funding will be tightly focused on the core transport network where there is most EU added value. To prioritise east-west connections, almost half the total EC transport infrastructure funding (€11.3 billion from the Connecting Europe Facility, CEF) will be ring-fenced only for cohesion countries.

3.2 RAIL FREIGHT CORRIDORS- RFC & RAIL NET EUROPE- RNE

Six international rail freight corridors became operational on 10 November 2013 and three more in 2015. These will foster international freight transport by rail, making this transport mode more competitive. Within the six corridors, rail infrastructure managers (IMs) cooperate across borders in order to markedly improve service quality and reliability. Freight trains will benefit from high-quality train paths with attractive journey times and common punctuality targets.

In the Rail Freight Corridors (RFCs), railway undertakings and applicants such as shippers, freight forwarders and combined transport operators can request pre-arranged, cross-border train paths at a single contact point, instead of having to submit individual requests to several national infrastructure managers (IMs) – this will lighten their administrative burden and speed up proceedings.

The six corridors are the Rhine–Alp Corridor, the North Sea-Mediterranean Corridor, the Atlantic Corridor, the Mediterranean Corridor, the Orient Corridor and the Eastern Corridor, see figure 3.1. Since there is much overlap between RNE's own corridors – of which the first eight were launched as early as 2005 – a transition phase has begun. During this phase, some RNE Corridors are being merged into the future network of Rail Freight Corridors: where an RFC matches an RNE Corridor, the function of the RNE Corridor Manager will be integrated in the RFC organisations' tasks in order to avoid any work duplication. In other cases, RNE Corridors will continue as they are. Current RNE Corridors 2, 5, 6, 8, 9 as well as parts of 10, are being replaced by RFCs 1, 2, 4, 6, 7 and 9.

Yet for parts of the European rail network where no new corridor organisation is planned yet, RNE is maintaining its RNE Corridors for the benefit of both the Infrastructure Managers and their customers.

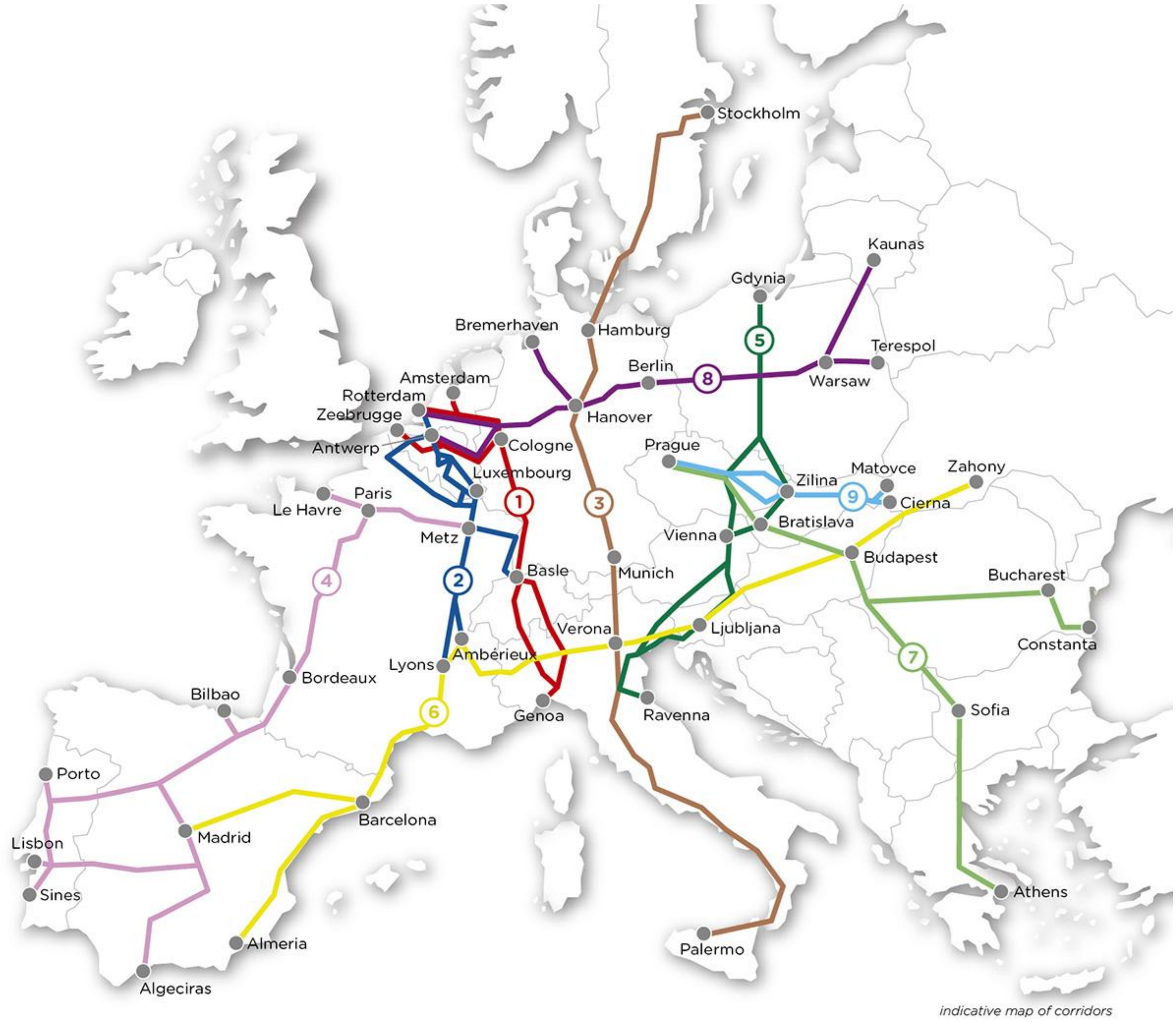


Figure 3.1: Rail Net Europe Rail Freight Corridors. Source: RNE, 25 November 2013.

3.3 ERTMS CORRIDORS

ERTMS (European Rail Traffic Management System) is intended to replace more than 20 different national train control and command systems in Europe, which are a major technical barrier to international rail traffic. ERTMS introduces considerable benefits in terms of interoperability, maintenance cost savings, increased safety and increased traffic capacity. By making the rail sector more competitive, ERTMS helps to level the playing field against road transport and ultimately provides significant environmental gains. There is an estimated 33,000 km of railway tracks contracted to be equipped or are already operating with ERTMS in the world, nearly 50% of which are outside the EU.

Together with railway stakeholders, the European Commission has established a list of six priority corridors for the deployment of ERTMS, see figure 3.2. These are major European rail freight axes, where the deployment of ERTMS will bring considerable benefits:

– Corridor A runs from Rotterdam to Genoa;

– Corridor B: Stockholm-Naples;

– Corridor C: Antwerp-Basel;

– Corridor D: Budapest-Valencia;

– Corridor E: Dresden-Constanta;

– Corridor F: Aachen-Terespol.

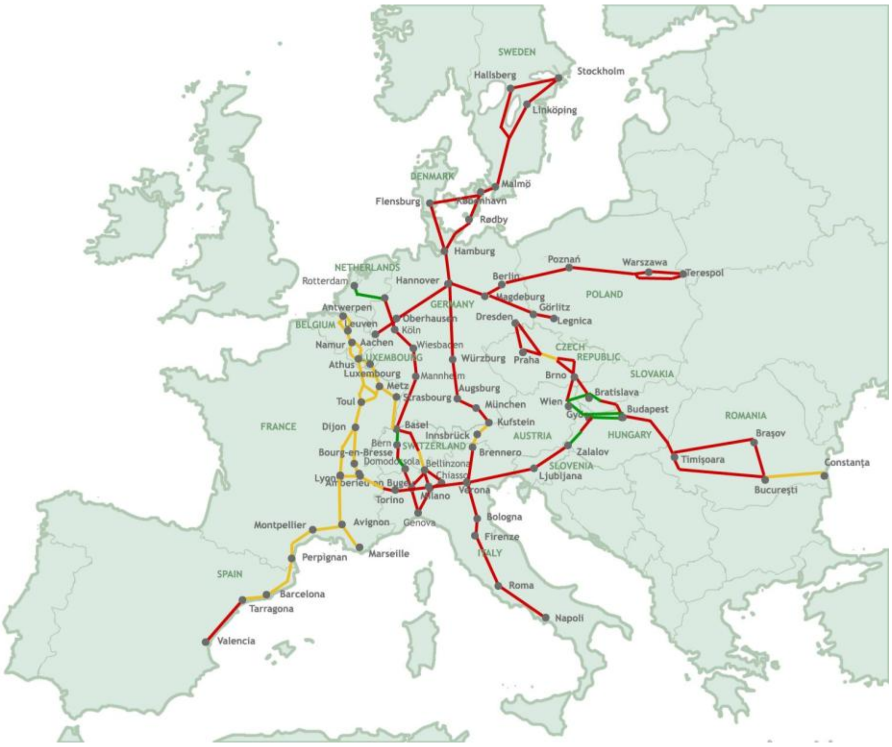
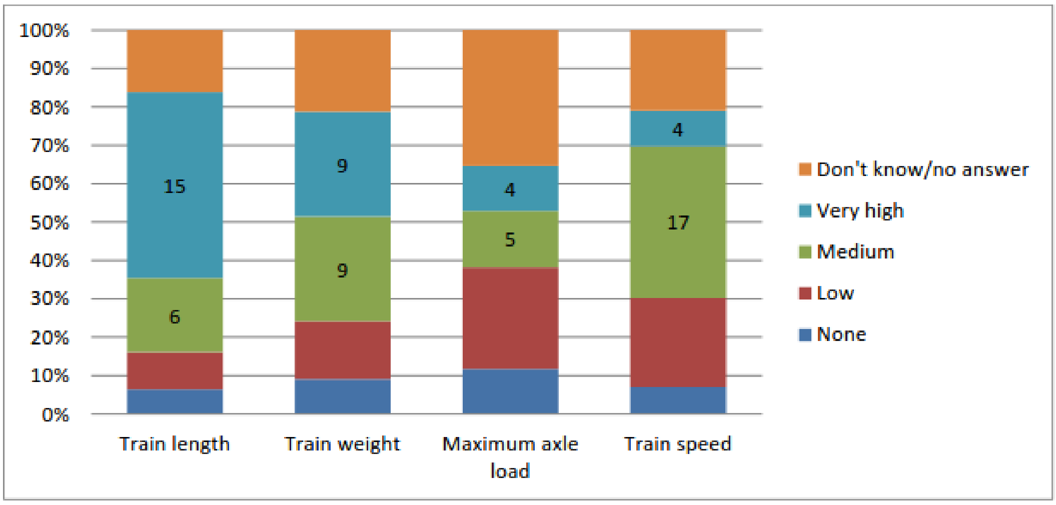


Figure 3.2: ERTMS corridors in Europe. Source: Unife, ERTMS news.

In the Transport Market Study carried out in 2014, increased train length was followed by train weight as the second most important parameter to improve the competitiveness of rail freight traffic. The results from the study are presented in Figure 3.3.

Figure 3.3 Influence of technical parameters on rail freight systems.



Source: Transport Market Study for Scan Med RFC (Consultants, 2014) page 187,

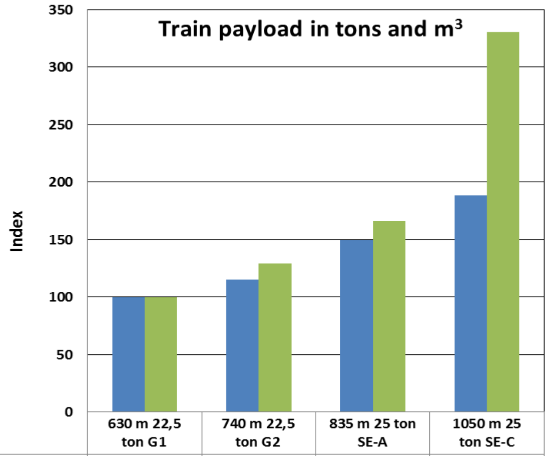
3.4 Maximisation of track capacity

From a transport buyer's perspective; capacity on rail is not only the capacity on the tracks, it is the capacity of the complete transport chain from point-of-loading to point-of-discharge. Any restraints or bottlenecks during the complete transport affects the capacity and reliability of rail freight transport, i.e. from the first to the last mile. The chain is not stronger than its weakest link. The transport buyer also intends to minimize the administrative work related to the transportation of the merchandise. The capability of the buyer to increase his/her workload should also be regarded as a bottleneck or capacity restraint, although this is a restraint not directly connected to the infrastructure or the rolling stock. However it is recognised that a transport buyer focuses on finding a cost efficient and reliable transport solution from point-of-loading to point-of-discharge with a minimum of his/her own resources needed to execute this transport.

Unfortunately, to choose a rail freight alternative in many cases will result in a higher consumption of internal resources for the buyer than choosing to transport the merchandise by road. Documentation procedures and general knowledge on how to transport goods by rail is vital and the rail transport alternative has the disadvantage of being more complicated than other modes with the need for more people to be involved.

A combination of actions, e.g. higher axle load, wider loading gauge and longer trains sometimes means that capacity in tonnes of volume, can remarkably extend capacity with the right measures (see Figure 3.4).

Figure 3.4 Combination of different standards for train lengths, axle load, gauge and capacity of a wagon-load train.



	630 m 22,5 ton G1	740 m 22,5 ton G2	835 m 25 ton SE-A	1050 m 25 ton SE-C
Ton Capapcity	100	115	150	188
M3 Capacity	100	129	166	331

Source: KTH calculations in the COINCOII-project (2014).

Construction of a high speed network would ideally increase capacity since trains could operate at higher speeds and also be more uniform in their driving behaviour regarding acceleration and braking. Furthermore if dedicated freight train lines are introduced, the freight capacity would be increased substantially. The possibility of running freight trains with a length of 1,500 meters would increase capacity considerably and a tremendous improvement compared with today´s restraints in train lengths partly due to mixed traffic on the tracks.
To support the maximisation of capacity it is a necessity to introduce both new and more efficient timetable planning systems as well as new train path ordering systems with a higher degree of interconnectivity between the RU´s and the IM´s. There is a lot of work and research going on in this area and if rail freight business is successful in introducing IT-systems, rail freight will be more reliable, robust and easier to administrate and coordinate in the future. Better train path utilization is a key aspect.

New innovations to reduce time at the marshalling yards, intermodal terminals and ports would also make it possible to run more trains. To what extent, is difficult to predict, but if a multiple set of actions (see figure 3.3 and 3.4) could be combined a threefold increase in the overall freight capacity might not be impossible. But to reach a threefold increase in capacity would definitely require large investments in infrastructure. Also the process of developing fully integrated European corridors and to overcome national safety rules is going currently too slow that needs to be expedited.

The diverging restrictions between European countries in allowed train lengths impose a major obstacle to the Railway Undertakings competing with road hauliers in international freight corridors. Allowed Train length differs from country to country and also within countries on different track sections, approximately from a maximum length at 550 meters up to 1000 meters. These diverging differences limit the train utilization and also impact the unit cost of rail freight transports.

In order for Infrastructure Managers (IM) such as Trafikverket, Network Rail, DB Netz to offer reliable and efficient train paths to the railway undertakings another major limitation is the availability of siding tracks deviation tracks, passing tracks and passing stations on a specific freight corridor.

To be able to create a truly integrated rail freight systems with increased capacity investments the actions above are necessary. For an IM to be able to offer efficient train paths for longer trains on a regular and standardized basis more siding and passing tracks are needed.

4 Rolling Stock

4.1 Brief review of the current fleet of wagons

The first characteristic of the present fleet of freight wagons is their relatively old age. This is due to the fact that wagons are technically able to live a long time before being scrapped. If properly maintained they are often terminated sooner than necessary when new wagons appear with a higher efficiency. This leads to a higher productivity but also a viable business model more profitable than existing wagons. This means that the old wagons are made obsolete when they become commercially obsolete.

In recent years, most new wagons built are specialized wagons for specific commodities or special types of transport, with specifically optimized designs and technical characteristics. This is true for bulk traffic, dangerous goods, steel products, finished new vehicles, combined transport of containers, swap bodies and transport of semi-trailers (vertically or horizontally handled) or articulated lorries. New wagons generally built for specific traffic are intensively operated, on these wagons progress may also occur on sub components like the bogies, braking system of the wagon, coupling system in order to reduce the LCC and to increase the payload, or the usable length or volume. However new wagons are now built with a flexible superstructure in order to accommodate various types of general cargo or intermodal units.

It is important to analyze the progress in comparison with the most frequent type of wagons in the segments where potential developments will justify technical innovations, certifications, tests and sometimes experimental periods before a full market uptake.

For these reasons car transportation has been the focus, as the second hand market seems to be developing strongly while the newly finished car market was slowing down, on the combined transport segment involving maritime container transport growing significantly with a high degree of concentration on major ports either directly served by deep sea giant container vessels or indirectly by feeder vessels, involving the trans-European swap body transport but also the crane-able or non-crane-able semi-trailer trailer transport where important development can be expected.

Figure 4.1a Currently used different types of wagons.

Figure 4.1a Car carrier wagon

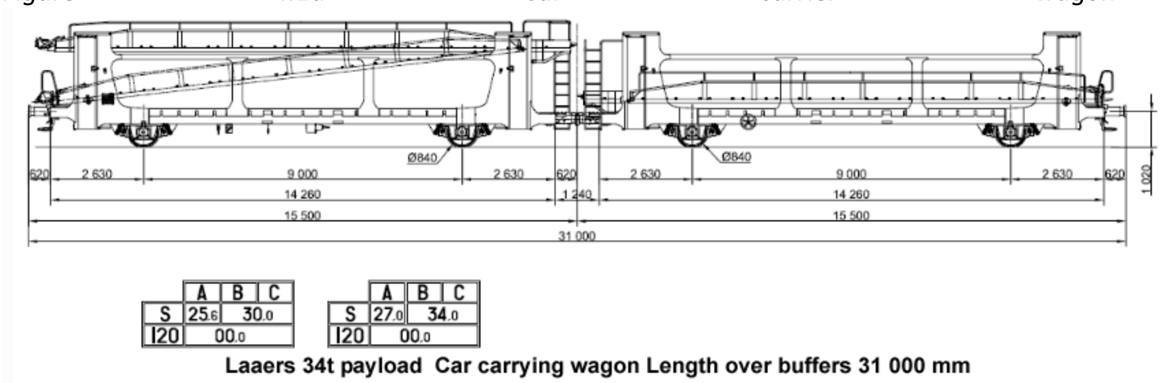
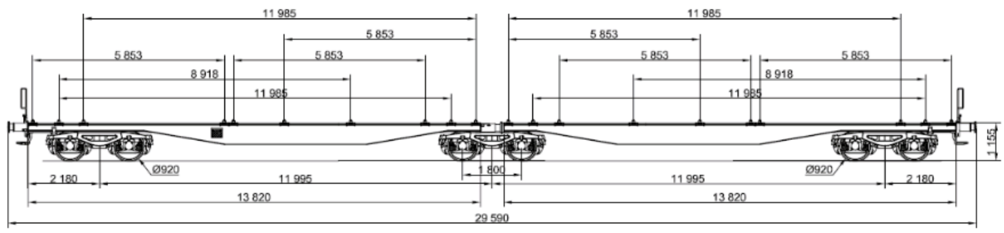
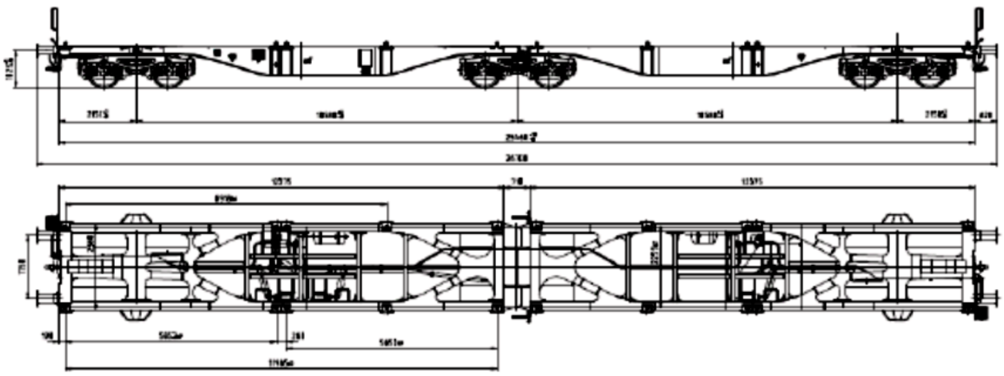


Figure 4.1b Flat wagon transporting maritime containers.



	A	B	C	D
S	68.8	80.8	95.8	107.8
SS	68.8	80.8	92.8	

Sggmrss 90' 6 axle container wagon for 40' or 45' containers



Sggrss 80'_2 6 axle container wagon Length over buffers 26700 mm

Figure 4.1c Pocket wagon transporting crane-able semi-trailers.

WAGONS INTERMODAUX

Wagon double poche T3000e

GÉNÉRALITÉS

Tare	34.3 tonnes
Charge par essieu	22.5 tonnes

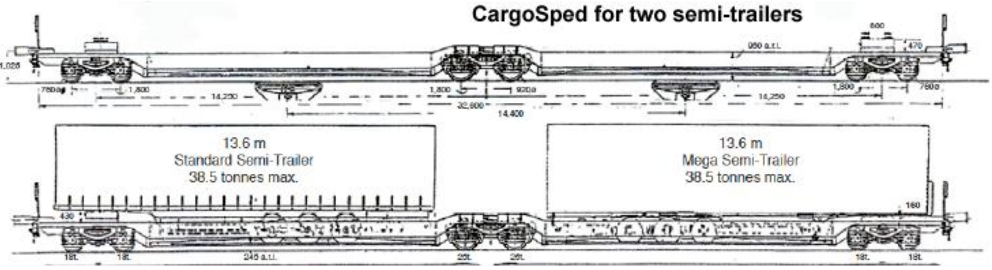
CHASSIS

Longueur hors tampons	34.20 m
Tampon	UIC 526-3, Groupe L
Bogies	Y25Ls(s)i / Y25Ls(s)i1(f)
Essieu	BA 004
Frein	2 x DK-GP-A-(K)

PLAN DE CHARGEMENT

Plan de chargement	Semi-remorques, grands conteneurs et caisses mobiles de longueurs diverses (de 20' – 45')

Figure 4.1d Pocket wagon transporting non crane-able semitrailers.



4.2 Technological development of wagons

4.2.1 Running gear

A review of freight wagon running gear designs can be found in [Jönsson, 2002]. For low-density goods, single-axle running gear designs are common, whereas (two-axle) bogies are needed for heavier products. Three-piece bogies are most common worldwide, but such bogies are rare in Western Europe. Instead, link suspension bogies and Y25 bogies are common. The most common bogie configuration is for each wagon to have two two-axle bogies, but for intermodal transport units three bogies with the middle one supporting two wagon frames are frequent (called Six- axle articulated wagon; or Twin wagon).

Efforts are being made to reduce the tare weight of the wagons, including the running gear weight through lighter bogie frames. See for instance [TU Dresden & TU Berlin, 2012] and [Iwnicki et al., 2013]. Higher (static) axle loads should, at least partly be compensated for by lower quasi-static (curving) and dynamic track force contributions to mitigate the impact on and deterioration of the track and the running gear themselves. Improved radial steering of the bogies during curving would give a positive contribution in this respect, see the Y25 bogie example in [Iwnicki et al., 2013]. More resilience in the secondary suspension is of interest, as is lowered wagon centre of gravity.

Higher top speeds, say up to 120-140 km/h, increase the average speed and thus reduce transport times. For mixed traffic lines, faster freight trains can also fit into the timetables better. Each freight wagon can in principle increase its weekly transport capacity in this way. However, increased top speeds typically lead to increased risk of ride instability and larger track impact. The running gear suspension design is again crucial to compensate for the effects of higher speeds, see [Iwnicki et al., 2013]. For instance, the traditional friction damping devices may have to be accompanied by rubber elements and/or hydraulic dampers. The classical trade-off between ride stability on straight track and track-friendly performance in curves must be studied as well as both empty and fully laden wagons. For delicate goods, ride comfort (carbody vibrations) is also an issue. Reducing the unsprung (wheelset) mass is of interest, but may require a smaller wheel diameter than the standard 920 mm. While, an advantage of higher speeds in curves is that the cant excess becomes smaller, likely leading to less settlement of the inner (lower) rails.

Today there is often a lack of incentives to develop freight wagon running gear with improved performance such as allowing higher axle loads and higher speeds as well as causing less track deterioration and wheel damage. For special transport applications, business cases can be found but usually running gear design development is incremental, starting from existing and internationally standardized design solutions. However, one important step forward is that rail infrastructure managers should have knowledge about the benefits of track-friendly running gear and in the future have the possibility to adapt the track access charges more closely to track deterioration.

Some alternative freight running gear designs than those indicated above are presented in [Jönsson, 2002] and from the European research project SUSTRAIL [SUSTRAIL].

4.2.2 BRAKING

Although freight trains do not usually make frequent stops for unloading/loading goods, train braking is common to accommodate reduced line speeds and stop at sidings for more prioritized (passenger) trains, together with stops at red signals along the railway line. From a freight transport capacity perspective this is of course a disadvantage. However, efficient braking through significant retardation can increase average speed and reduce transport time (but is not the most energy-efficient braking in case the locomotive has regenerative braking).

Unfortunately, the retardation is usually less than 0.5 m/s^2. This is mainly due to the slow pneumatic braking systems that dominate among freight trains in Europe. The most well-known braking system in this class is the pneumatic (P) braking system as defined and standardized by UIC. Other limiting factors are the use of cast iron brake blocks, with strongly speed-dependent friction, and lack of wheel-slide protection system. The devices for payload-dependent braking capacity also typically give less retardation at higher loads (in Europe usually above 18 tonnes axle load).

An increase in transport capacity by allowing higher axle loads thus often means lower retardation, mainly to avoid wheel tread damage, and extended transport times. Alternative brake block materials, like composites or sinter, and modified wheel steel types may mitigate this situation. A more drastic remedy is to abolish block braking and go for disc braking, but the business case is probably questionable for high axle load and low speed operation.

Increasing transport capacity by means of higher top speeds certainly raises the demands on braking. For top speeds of 140 km/h and more this usually calls for disc braking. But the increased speed is usually motivated by high-value, and fairly low-weight, goods and the additional cost associated with implementing disc braking may be justifiable.

Another way to increase transport capacity is to run longer trains. This option is also strongly related to train braking performance. Today, the maximum freight train length in Europe is typically 650-850 m, and the traditional UIC P-braking system does not really allow for longer trains. Since the braking signal in this system only relies on the air pressure drop propagation down the train braking pipe, with a typical propagation speed of less than 100 m/s, the braking synchronization along the train will be poor and result in significant compressive forces between wagons that may cause train derailment. The brake application time in the freight train locomotive is therefore long (20-30 s) and the maximum brake cylinder pressure limited.

Longer freight trains than indicated above therefore call for some kind of improved braking system. One way is to introduce an end-of-train (EOT) valve that will release air from the braking pipe at the end of the train, thus also giving an air pressure drop signal propagating forwards along the train. A relatively inexpensive approach to quickly activate the EOT valve when braking is to use radio communication, although loss of such communication for a few seconds may occasionally occur.

The main alternative to radio (wireless) communication is to introduce an electric cable (wire) along the train to virtually guarantee synchronous braking along the train and thus, for an ideal payload-dependent braking, very small longitudinal compressive forces between wagons as well as shorter braking distances and higher average speeds. This concept is used on modern passenger trains and many long freight trains outside Europe. However, this electronically controlled pneumatic (ECP) braking system is difficult to introduce in the traditional draw gear design of freight wagons with screw couplers and side buffers. On the other hand, an electric supply can also be used for wheel-slide protection systems, condition monitoring and other purposes.

When it comes to braking and draw gear, (automatic) centre couplers transfer both compressive and tensile forces and typically allow higher longitudinal forces and also longer and heavier freight trains.

It should be pointed out that braking is also closely related to the railway signalling system and its speed reduction supervision with advance warnings at certain distances.

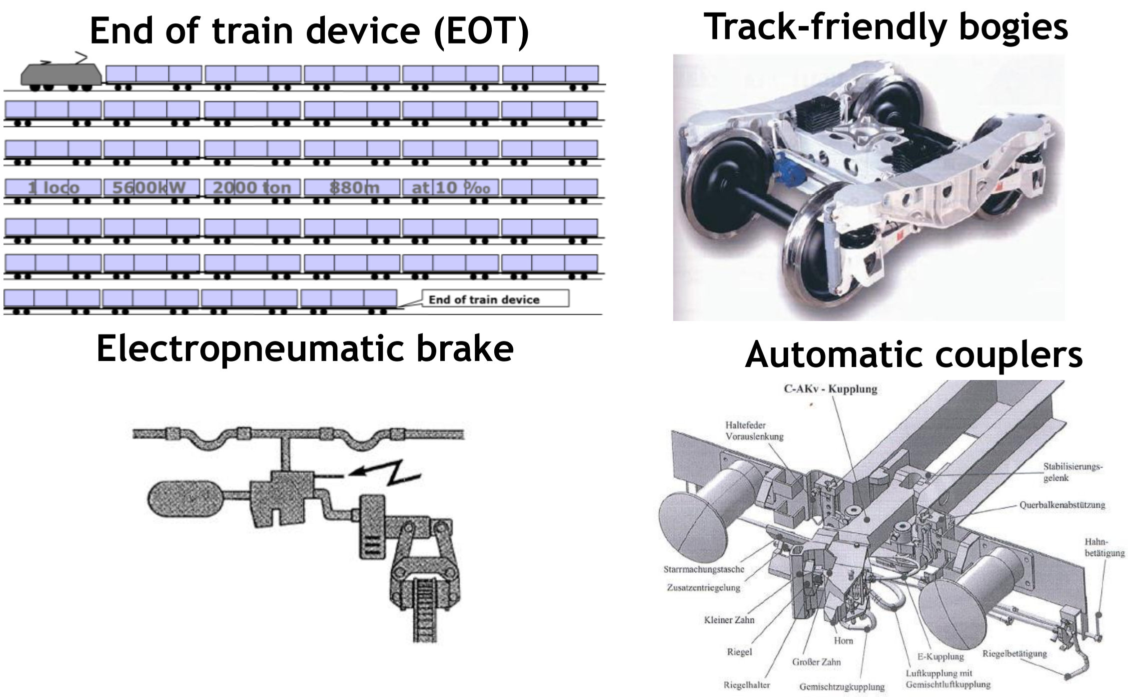


Figure 4.2: Examples of different components for future freight wagons. Source: KTH.

For further references on freight wagon/train braking, see for instance UIC540 [UIC, 2002], KTH [KTH Railway Group et al., 2005 & 2013], Marathon [Marathon] and SUSTRAIL [SUSTRAIL].

4.2.3 Noise

Noise from passing freight trains is a serious issue that jeopardizes the entire rail transport capacity. Legislation, not least in Europe [EC, 2011], today enforces strict noise limits on the dB sound pressure scale and more restrictions on the design of new freight wagons. In densely populated areas, speed restrictions may be required, in particular at night.

For typical top speeds of around 100 km/h, the major source of freight train noise is from the wheels rolling on the rails, not least in tight curves, and is worsened due to the typical lack of non-metallic components in the running gears. However, the main concern is usually associated with the noise emitted during braking. The situation can be particularly annoying for freight trains equipped with cast iron block brakes. In Europe, this has led to new freight wagons not being allowed to use cast iron blocks [EC, 2011]. Existing wagons may have to be retrofitted.

Alternative and less noisy block materials are composites and sinter. A list of approved K-composite brake blocks is given in [ERA, 2011]. Disc braking, in particular with wheel-mounted discs, may be another option to reduce noise levels. However, the discs will increase the unsprung mass while maintenance cost of certain composite brake blocks (LL-Type) are quite high because of wear on the wheel which has to be reprofiled frequently. With K-Block the problem is that the wagons have to be fitted with auto-variable braking system which is quite expensive. Progress has still to be made on Brake Blocks to economically solve the noise problem.

Resilient rubber components in the running gear suspension and wheels can reduce the noise to some extent. For reduced rolling noise, smooth wheel and rail running surfaces are important. In tight curves, typically with less than 600-700 m radius, trackside lubricants often have to be applied to reduce rolling noise as well as wheel and rail damage such as wear. Another traditional infrastructure action to reduce the railway noise experienced by residents etc is to introduce noise-reducing screens along the railways, but the associated costs are high and future development should focus on the sources of rolling noise and braking noise.

For further references on noise from freight trains, see for instance KTH [KTH Railway Group et al., 2005 & 2013] and SUSTRAIL [SUSTRAIL]. The review paper by Thompson and Gautier [Thompson & Gautier, 2006] should also be mentioned.

4.3 Energy consumption and emissions by trains and wagons

Affirming that the energy consumption of a freight train is a specific value without having any thoughts about it, leads us to make a big mistake. High variability is found in energy consumption and emissions that represent the exploitation of freight trains. An accurate method capable of showing factors that most strongly impact the performance in terms of consumption and emissions is required. The use of an equation for unit energy consumption is important to allow a better understanding and improvement of energy consumption. Empirical evidence is needed to ensure better calibration of the equation.

Unit energy consumption per tonne-kilometre was estimated for two types of profile (smooth and mountainous) in different railway vehicles. The results show that the operating parameters that depend on the type of profile, such as speed, number of stops and braking, have a great influence on the total energy consumption of vehicles and consequent consumption per unit of transport tonne-kilometre. Parameters depending on the type of vehicle and independent of the type of profile, such as vehicle mass, rolling resistance and drag, also have a significant impact on energy consumption. In any case, unit energy consumption and the consequent CO_2 emissions presented in this study correspond to a special case in the Spanish railway environment, and therefore may be different in others.

The results show that energy consumption per equivalent tonne-kilometre is strongly related to the maximum net tonnes carried so that the correlation between unit consumption and total consumption, in loaded and empty vehicles, is high. Total consumption relates to the vehicle's mass since almost all the vehicle's energy losses (rolling resistance, aerodynamics, gravity and kinetic energy) depend on its tare. According to the results of this research, a combination of vehicles with a high ratio of net tonnes carried with respect to tare, with low rolling and drag coefficients, operating in constant speed profiles with few stops leads to lower energy consumption per equivalent tonne-kilometre.

Finally, from the energy consumption and emissions generated by the transport of a "dense" reference product (petrochemicals), for a given load, with electric traction and on a smooth line profile, it is possible to approximately estimate the energy consumption and emissions of different compositions by multiplying the reference composition for the following values:

- To determine the consumption of a composition with diesel traction, the consumption of the reference product is multiplied by a value between 2.15 and 2.60.
- To determine the consumption of a car carrier ("light") train with electric traction, the consumption of the reference product ("dense") is multiplied by a value between 2.08 and 2.33.
- To determine the energy consumption in a mountainous profile, based on the emissions in a smooth line profile, emissions are multiplied in the case of "dense" trains by a factor between 1.7 and 2.1 and in the case of "light" trains by a factor between 1.7 and 1.9.

It can also be said that from 300 net tonnes (when the load carried is increased, the train length increases) transported in all compositions, consumption and emissions have an asymptotic trend that remains fairly constant.

4.4 FUTURE SAVINGS IN ENERGY AND GHG

Regarding improved energy and GHG efficiency of rail freight transport, extensive work was carried out in the EU project TOSCA [TOSCA, 2011]. Actions were identified and most of them are also linked to the economic efficiency of rail freight transport, briefly discussed below. Savings are given in percent per unit load (tonne-km) by 2050 in comparison with the reference system of 2009. A likely increase in top speed of 0.3-0.5% per year is not considered below.

Low-drag freight train

Technologies are available for reducing air drag by 20–25 % compared with the reference trains. A transition from open towards covered wagons is already under way but not all freight wagons can be covered for practical and operational reasons. For example, in intermodal transport different load carriers are loaded on open railway wagons with some 2–10 m longitudinal intermediate gaps. The low-drag freight train is at this stage estimated to have an energy-saving potential of up to 10 %. There is a large potential for improvement in the loading of intermodal units where the intermediate gaps should be minimized by appropriate loading strategies and flexible wagons.

Low-mass freight wagon

Lower tare mass of freight wagons can allow more loading of heavy goods in each unit, while maintaining limits for permissible total mass and axle load. This will reduce energy and related GHG emissions (per tonne-km) in cases where total wagon mass is a limiting factor. The potential for energy savings is estimated to be 5–8 % in heavy haul freight trains and about half of this in other trains. Both design changes and material substitutions are needed.

Energy recovery

Most modern European electric locomotives for freight haulage use their motors as generators when braking, thus feeding back electric energy to other trains on the line. This technology is already in use but may be further improved and introduced. At this stage, a further 4–8 % reduction in net energy use per tonne-km is expected in the medium term until 2025. About the same savings can be achieved by using electric recovery brakes as the normal braking mode, which will however delay the train by 40-60 seconds per braking – which can be accepted if the train is not running late. Such braking will also reduce the maintenance of the mechanical brakes.

Heavier freight (axle load + loading gauge + longer trains)

European freight trains are usually fairly light, with a limited length, axle load and loading gauge. This makes rail freight services less efficient on cost and energy usage than technically necessary. This is obvious in comparison with North America, where an average long-distance freight train is 5–10 times heavier, while the permissible axle load is almost 50 % higher. In addition, the standard loading gauge is about twice as large in North America than the most commonly used loading gauge (G1) in Europe. In the long term (until 2050), a 20 % increase in axle load (from normally 22.5 tonnes to 27 tonnes) and an enlarged European loading gauge - from gauge G1 or G2 to at least gauge GC – would lead to 15–20 % energy savings relative to the reference trains. Increased axle load is useful for heavy high-density freight and improved loading gauge for low-density items. It is to be noted that to achieve such efficiency these increases must be implemented on the whole train journey. Some further improvement in energy performance can also be achieved by increasing the train length.

High-efficiency machinery

Electric power technology is continuously improving both for high-powered electric motors and their feeding converters. This opens the way for improved energy efficiency of new freight train locomotives, both straight electric and diesel-electric. Improvements in the electric power supply system of the rail infrastructure are also anticipated. In all, losses in these systems are anticipated to be reduced by about 30% in the long term relative to the reference trains. For example, losses in locomotives are anticipated to be reduced from 18% to about 13% and in electric power supply from 9% to 6%. Diesel locomotives can take advantage of the continuously improving diesel engine technology, with fuel consumption assumed to be reduced by 8% in the long term.

Eco-driving

Optimization of driving style means, for example, coasting before braking and downhill approach, use of regenerative brakes as the ordinary brake, running slowly when time allows, etc. In the short and medium term, such optimization is estimated to have a saving potential of 8–10% compared with the reference case of average manual driving. To some extent, these technologies have already been commercially introduced, but are estimated to be improved and can be fully implemented on modern freight trains within the next 5–10 years. In the long term, this technology may be co-ordinated with rail traffic control, which would lead to further improvement and also enhance railway transport capacity to some extent. The potential of total energy savings by 2050 is expected to be at least 12–15%. It should be noted that in some cases eco-driving can be contradictory to efficient use of network capacity. One of the most important economies is to avoid as much as possible, stopping the train by an adequate speed control under indications given by the train regulator to avoid conflict of train movements.

Dual mode and hybrid locomotives

Today, many freight trains running on both electrified and non-electrified sections use diesel power only, in order to avoid changing locomotives. In dual mode locomotives, electricity is used on electrified railways while diesel or bio-fuels are used in combustion engines on non-electrified sections, including industrial sites. Depending on the share of electrified sections in the actual operation and the carbon-intensity of the electrical supply, emission reductions may be in the order of 20–50 %, compared with the reference pure diesel operation. Another possibility is hybrid diesel-electric propulsion with on-board energy storage, which in diesel operation can reduce energy and emissions by 10–15%. This technology is partly available today, but is sparsely used. Applications are limited to diesel-hauled operations, i.e. a theoretical maximum of 15% of total rail freight in Europe.

Bio-fuels in diesel engines

As with road vehicles diesel fuel can be substituted by liquid or gaseous bio-fuels. The maximum market penetration is 15%, i.e. the market share of diesel-hauled rail freight. But it is anticipated that bio-fuels will be reserved mainly for use in airplanes and long-distance road transport.

Electrification of non-electrified lines

Electrical rail operations are usually much more energy- and GHG-efficient than diesel operations. Some European countries have today a very limited part of their rail networks electrified. In these countries, substantial reductions in GHG emissions are expected, in particular if 'Low-GHG electric power' is used in the future (see below). Massive electrification to cover, say, 95% of all European rail transport (instead of the present-day 85%) would reduce GHG emissions on non-electrified lines. However, the overall effect would be limited and the GHG reduction is again dependent on the GHG emissions of energy conversion into electricity. The limited overall impact - because of the low additional market penetration - and the associated cost of electrification are a matter of optimization.

Low-GHG electric power

Electric power in Europe is essentially produced by fossil fuels, renewable energy sources and nuclear power. In 2009, fossil fuels had about a 50% share of the total. Tomorrow's long-term electric power mix must have substantially diminishing dependence on fossil fuels if GHG emission targets are to be met. At the consumer level, GHG emissions in 2009 were estimated to be 460 gCO_2-eqivalent per kWh electricity from the public grid with the EU27 electric production mix (128 gCO_2-eq per MJ). Substantially reduced GHG emissions from electric power generation will be one of the most effective means of reducing emissions from the European transport sector, not only for railways but probably also for passenger cars in the road sector. Reduction of the GHG content by 80% will reduce specific emissions of electric trains by the same amount. Market penetration in the rail sector is as high as 85% (i.e. diesel operations are excluded).

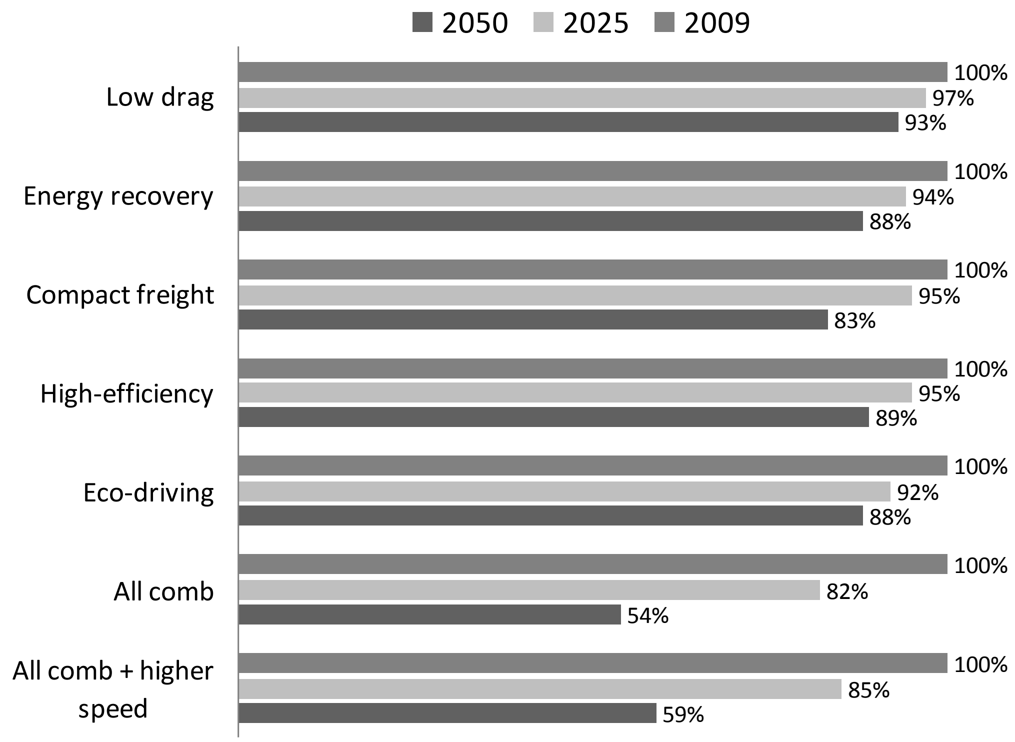


Figure 4.3: Estimated trends of energy use (per tkm) by technology over time, including all combinations and higher speeds, aggregated and weighted over all types of electric rail freight services. Source: TOSCA (2011).

In table 4.1 measures are listed to reduce GHG in the rail system and in the transport sector as a whole by making rail more efficient and increase market share on behalf of modes with higher relative GHG-emissions.

Table 4.1 Overview of measures to reduce GHG and make rail more efficient. Source: STTP 2012.

	System development	**Technical development**
To reduce GHG in the rail system		
In the rail system	Eco-driving Improved load factor	Space-efficient & compact trains Energy recovery Low drag trains
In the energy supply	Electrification of diesel-operated lines Production of low-GHG electricity	Dual-mode locomotives Hybrid trains Biofuels in diesel engines
To reduce GHG in the transport sector		
Passenger transport	Extension of High Speed Rail network Investments in EU 12	Technology for higher speeds Running gear for smoother ride and lower dynamic forces

	Market liberalization for lower prices Development of customer-oriented intra-modal and intermodal network	Space-efficient trains Modular trains More efficient trains at reduced cost
Freight transport	Implementation of deregulation in practice to improve supply Seamless rail freight corridors through borders Investments in EU12 Development of dense inter-modal network	Lighter wagons with less noise Running gear for higher axle loads and speed Higher axle load and larger loading gauge Electro-pneumatic braking Distributed radio-controlled power Automatic couplers Intelligent freight wagons and trains Terminal technology for horizontal automatic transhipment
Infrastructure	Implementation of longer freight trains Higher axle loads and wider loading gauge Faster freight trains	Cost-efficient slab track Long-life cross-ties Low-cost track
Traffic management and IT	Implementation of ERTMS	ERTMS level 3 Automatic operation
New modes		Magnetic levitation trains Vacuum tunnel trains Personal rapid transit (PRT)

4.5 FUTURE DEVELOPMENT OF WAGONS

The rail freight business has to come up with new innovations to meet the customer requirements by developing, for example, flexible wagons. The main focus should be to improve efficiency, reliability and to contribute to decreased transport costs from the *initial* place of loading to the final destination. It must be noted though, that the progress in rail freight transport does not simply rely on specific progress for wagons. It incorporates progress of train efficiency resulting from the development for certain sub components allowing a progress in reliability, LCC, maneuverability. This progress allows the application for better paths on the network impacting positively on the use of assets, the driving costs, and the smoothness of transfer at hubs or marshalling yards. Of course new designs are fundamental as well as the use of new materials impacting positively available payload, usable length and usable volume on a given train. Moreover the progress on wagon connectivity allows information to be updated and given to interested stakeholders on the progress of the train, its ETA, status of the wagons and cargo.

It seems adequate to analyze the future wagon image on the basis of common new characteristics and then to develop the specific characteristics of the wagons adapted to specific market segments.

- Common new characteristics:
    - An electric line along the train carrying energy to activate a series of sensors to monitor the wagon and the cargo status but also carrying a lot of information concentrating that information for transmission to interested stakeholders;
    - Lighter and more track friendly bogies equipped with more silent brake shoes
    - A new braking system with electronic valves activated electrically for a synchronous braking of all wagons. In an interim period this new braking system should be overlapping the classical pneumatic braking system acting as a back-up.
    - Install an end of train device electrically and pneumatically (as a back-up) activated.
- Specific characteristics:
    - For wagons dedicated to bulk traffic
        - For shuttle trains replace UIC couplers by drawbars inside blocks of several wagons , the blocks being coupled by central automatic couplers (for traction and compression)
        - Use lighter, new materials for the wagon structure providing equivalent resistance.
    - For combined traffic
        - For the transport of only 45' maritime containers use new 5 bodies wagons of 72m long with six bogies and central automatic couplers at each end of the 5 bodies.
        - For the transport of mixed 40' and 45' maritime containers use classical 40' wagons with specific extension on the middle wagon of a block of 3 enabling to place a 45' container.
        - For the transport of crane-able swap bodies use classical T3000 wagons which might be optimized with the general improvements quoted here above.
        - For the non-crane-able semi-trailers they must be flexible for carrying 45' high cube maritime containers and semi-trailers with a very low floor and a very quick loading solution implying simultaneous loading. Because of the high cost of such wagons creating blocks of several wagons to gain usable length and using central automatic couplers between the blocks and an end of train device to enhance the possible global length of the train will be necessary.

- For wagon load traffic, wagons will be equipped with tags of identification of the wagon and of the cargo and central automatic couplers by group of two wagons linked by drawbars.
- For finished car carrier wagons the new built should be 65m long wagons with 5 bodies and 6 axel to optimize the usable length.

5 Rail Terminal and Handling Technology

5.1 New concepts

The nodes concept encompasses various types of terminals such as; hubs, marshalling yards, freight villages, sea ports, dry ports, intermodal, conventional, multimodal terminals and industrial and logistics zones. To transform transit round the clock into added value by quick transfer between modes or from train to train, terminals are best located close to production and or large consumption areas or at corridor cross points.

Key elements of network management efficiency include high filling coefficient of trains or last mile transport, high degree of reliability for the end customer, capacity of finding the best connection to reach the end terminal by integration in the whole network. Terminals can also increase benefit by offering ancillary services and by good synchronization between the arrival of the transport vectors (long and short haul trains, trucks, barges and planes), the operations in the node and the departure of the next transport vector. ICT integrators, customs clearance and information dissemination to interested actors are paramount. In addition, the effective design of the node is essential to avoid expensive costs of transfer between terminals.

Within the supply chain, freight terminals play a primary role in an efficient and competitive supply chain: they are the connection point between the transport nodes and the nodal points where the freight services handle, store and transfer between different modes to final customers.
Alongside this, they often represent the bottleneck of the freight transport network, where goods are often stored for long periods and trucks and trains experience delays in comparison with the time schedule.

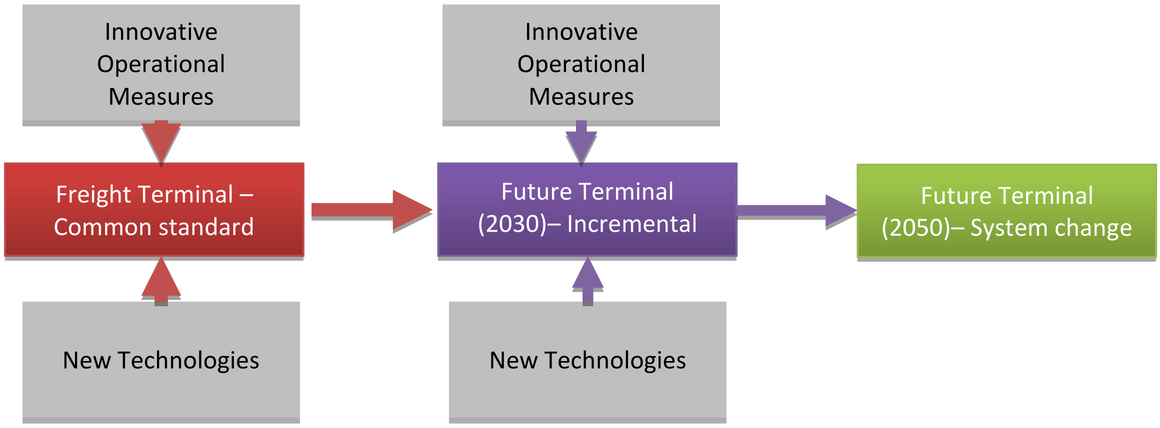
5.2 New technologies and innovative operational measures

New technologies and innovative operational measures discovered through previous research;

- New Technologies: physical elements that operate within the terminal, independently or components of existing equipment, which can be mobile or fixed (e.g., new gantry cranes, truck portals, intermodal complex spreaders, self-propelled wagons, etc.);
- Innovative Operational Measures: set of processes for terminal management (e.g. ITU transfers, terminal working periods, internal rules, etc.).

These innovations have been collected based on existing technologies and assuming an increase of their performances. The main aim is to decrease the Total Transit Time of the ITUs, wagons and vehicles inside the system, to operate higher flows, increasing the attractiveness of the system for customers. After a preliminary compatibility analysis, these innovations create future scenarios for different terminal typologies (Figure 5.1).

Figure 5.1 Conceptual future terminal scenarios. Source: DICEA.



The traditional trainload (TL) is the simplest form of wagonload: it needs only a load/unload terminal, and it has no change in train composition during the trip. The single wagonload (SWL) is a sophisticated product by which a wagon or a coupled group of wagons are shunted into the facilities of a shipper, and once loaded, they are marshalled to form trains that run over longer distances.
In conventional freight transport, the loading/unloading terminals operation and facilities for the handling of goods are closely dependent upon goods type, though it does not need integration with other modes.
Combined transport offers the possibility of rapid transhipment of goods, as goods travel in loading units (container, swap bodies, semitrailers, even truck itself, in the case of accompanied transport).
This implies the shipment of goods from an origin to an intermediate destination and from there to another destination. The transhipment takes places in terminals or hubs where the freight is consolidated or deconsolidated and allows the change of the transport modes during the journey without handling the goods as such.
When considering economic and functional factors, intermodal rail transport is the only sector which has grown in line or, in some cases, even higher than the growth of gross domestic product.
Moreover, it is also the type of transport best suited to international transport, integrating several transport modes, from road, to rail, to waterways, to sea and is the system that benefits most by interoperability process undertaken on the European rail network. By comparison, single wagonload traffic is in steady decline compared to intermodal traffic.

5.3 INTERMODAL RAIL-ROAD FREIGHT TRANSPORT

Rail-Road terminals are the place on a railway network where the goods are handled, stored and transferred between different modes to final customer; they are equipped with costly technology based on high complexity technological procedures demanding a high degree of coordination and control skills.
Great effort is exerted to find an optimal configuration of infrastructure to extensively exploit technical resources and to effectively organize technological procedures.
Evaluation of technological processes and their development in railway terminals enables successful functioning of transport, thus guaranteeing reliability and quality for the consignee.
Generally, they can be classified by location in the logistics chain (e.g. Hub and Spoke, Linear, Gate terminal), to dimensions (Large, Medium and Small) or transfer mode (Vertical or Horizontal).

5.4 Terminals with vertical handling techniques

Generally, this terminal typology is characterized by different operative modules according to the operated functions.
In particular, the main phases are:

- Train arrival (ITUs and Wagon check, locomotive change);
- Train entrance on transfer track (ITUs transfer, ITUs and wagons check)
- Truck arrival (ITUs, driver and trailer check, Assignment to transfer);
- Truck entrance in transfer area (ITUs transfer, ITUs and trailer check).

Each phase is characterized by:

- Layout elements: number of truck lanes, number of rail tracks, number of ITUs slots, distance, etc.
- Operative rules: vehicles speed limits, directions of traffic, priority of ITUs transfer, etc.
- Items flows: the four main categories are trucks, trains, ITUs and ITUs handling equipment.

New technologies and innovative operational measures can increase the performance of different phases.
The innovations are classified according to various elements of the terminal (layout, equipment, management, etc.) and time horizons (Table 5.1).

TABLE 5.1 RAIL-ROAD, INNOVATIONS ACROSS COMMON STANDARD, INCREMENTAL CHANGE AND SYSTEM CHANGE FOR A RAIL-ROAD TERMINAL. SOURCE: DICEA.

OPERATIONAL MEASURES			
	Common standard	**Incremental change (2030)**	**System change (2050)**
Handling typology	• Indirect and direct	• Mainly direct	• Faster and fully direct
Track operative length	• 550-850 m	• 750-1000 m	• 1000-2000 m
Working period	• Less than h24	• Partially h24	• Always h24
TECHNOLOGIES			
	Common standard	**Incremental change (2030)**	**System change (2050)**
Handling equipment in operative track	• Transtainer and reach stacker or forklift • Few systems for horizontal transfer	• Fast transtainer • Many systems for horizontal transfer	• Automated fast transtainer with moving train • Automated systems for horizontal and parallel handling
Handling equipment in storage area	• Transtainer • Reach stacker or forklift • Straddle carrier • Trailer (transport only) • Some AGV	• Fast transtainer • Automated transfer systems (e.g. container cross conveyor)	• Automated fast transtainer • Automated transfer systems (e.g. container cross conveyor)
Equipment, positioning and grab	• Manual • Manual with support technologies	• Manual with support technologies	• Automated
Equipment for vertical handling	• Spreader with twist lock • Spreader with grapple arms • Some intermodal spreader (grapple arms and twist lock)	• Many Intermodal spreader (grapple arms and twist lock) • Intermodal complex spreader (multiple ITU handled)	• Intermodal complex spreader (multiple ITU handling)
ITU/Vehicle identification and documentation exchange	• Manual control	• Manual control • Automatic control (automatic gate)	• Automatic control (automatic gate)
Security control	• Rare	• In most terminals	• In all terminals
OPERATIONAL MEASURES + TECHNOLOGIES			
	Common standard	**Incremental change (2030)**	**System change (2050)**
Locomotive	• slow with loco exchange (electrical-diesel)	• Fast with loco exchange (e.g. automatic coupling)	• Fast without loco exchange

5.5 LINEAR TERMINAL WITH HORIZONTAL TRANSFER

Conventional end point terminals are relatively expensive in both investment and operation but can handle all types of unit load, e.g. by means of a reach-stacker. They cover a relatively large area and must be dimensioned for very high axle loads. The fact that the terminal tracks cannot be electrified means that trains must be switched in with a diesel locomotive. Moreover, several tracks are needed to be able to park the wagons while they wait to be loaded and unloaded. These aspects contribute to the terminals being expensive, both for costs and spaces, and difficult to bring the cost per unit handled down even with large freight volumes. Intermodal traffic is traditionally operated as end point traffic, but it could be also operated as regular linear traffic, as soon as the terminal technology is compatible with it (Figure. 5.2).

A linear traffic terminal is located on a side track where the train can drive straight in and out onto the line again. This line could be electrified so that the train does not need to be switched in, which requires a handling technology able to operate under the overhead contact wires.
The train should be loaded and unloaded during a stop of 15-30 minutes. This also obviates the need to park wagons and the terminals can be more compact, with advantages in terms of cost-effectiveness in comparison with conventional terminals. With horizontal transfer of units all types of containers and swap-bodies can be handled and the terminal can be made compact and eventually automated. With linear traffic which means that the train stops on more terminals along the way a larger market can be reached.
By summarizing, the following main typical features can be identified:

- Loading and unloading under energized catenary;
- Independent train and the truck;
- Costs for terminal handling lower than with today´s equipment;
- Possible fully automated loading/unloading and storage;
- Modular and usable in both small and big terminals.

Normally, to make terminal handling even more efficient, an automatic transfer system is needed. One example of such a system is the Swedish CCT (CarConTrain) system, which was tested as a prototype but never reached commercial production.

Fig 5.2 Terminals for end point traffic and linear traffic. Source: KTH.

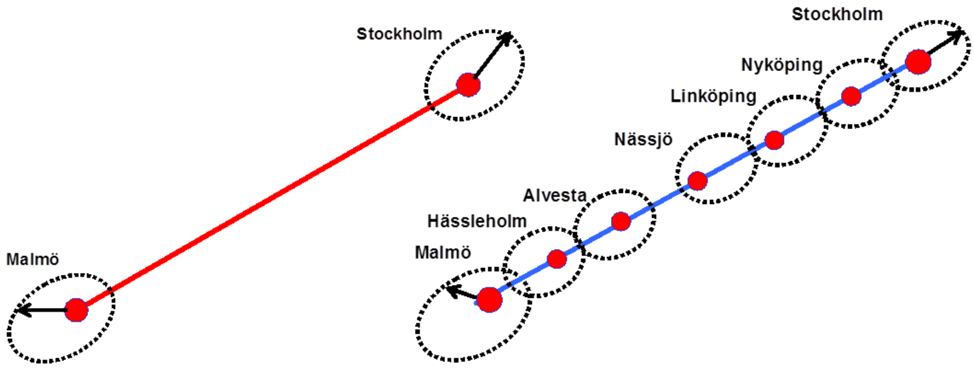
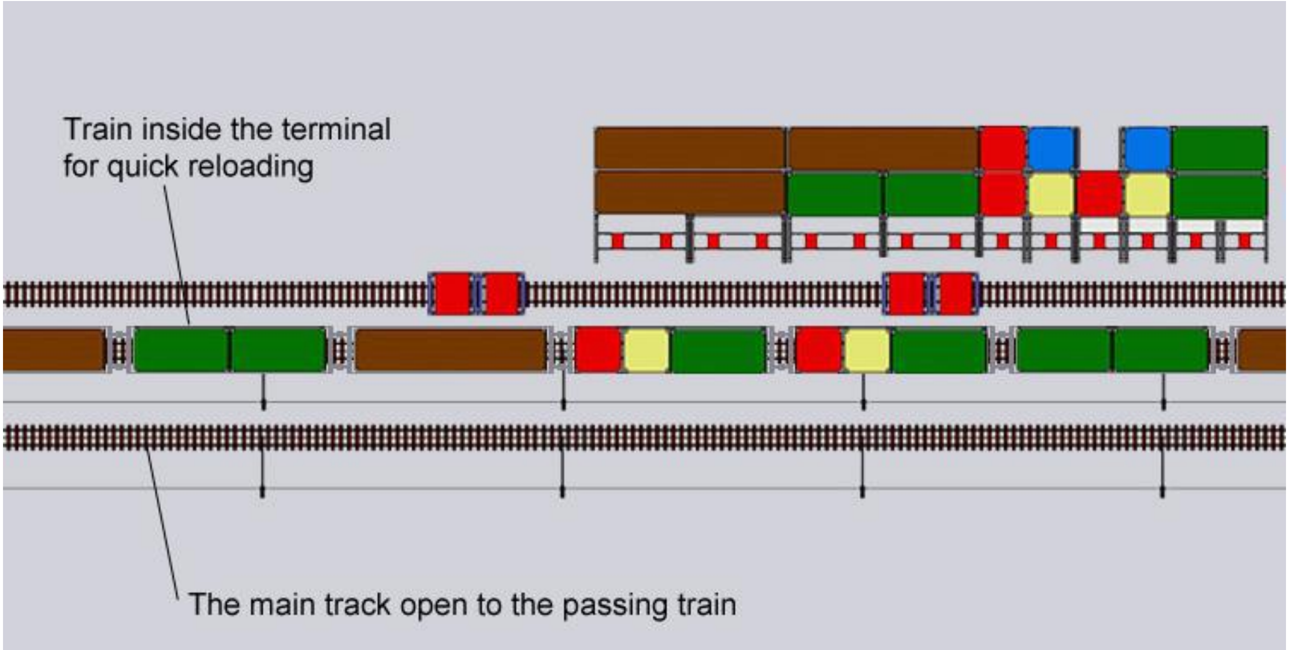


FIGURE 5.3: SMALL SCALE LINEAR TERMINAL WITH CCT SCHEME. SOURCE: CCT – AN INTERMODAL TERMINAL HANDLING SYSTEM FOR HORIZONTAL TRANSFER, 2014.



The system (Figure 5.3) consists of a wagon that travels parallel with the track, which is equipped with arms for transferring freight horizontally. The container is lifted a little way off the wagon by means of hydraulic, lockable container pins so that the arms can be inserted below it. The container is lowered onto the arm and transferred to the wagon. This can then move away, travelling parallel to the track, and leave the container in a storage area or transfer it to a truck for further transport by road. The system is built up of modules: one unit is required for small containers and several for larger ones. A transfer cycle takes about 90 seconds. The system can transfer units fitted with corner castings of 2.5 to 3.6 m width and 3 to 12 m length: In the automated version it could be used in unmanned terminals, warehouses, and ports: the train can be handled regardless the truck is available or not and can arrive at any time during the day, since no personnel is required, with enormous potential opportunities for more efficient logistics flows.

Another horizontal transshipment technology, recently operational in Switzerland is Innovatrain's 'ContainerMover 3000'. It is a horizontal technology that uses compressed air to lift the boxes so they can be laterally and hydraulically displaced from the railcar to the truck and vice versa (Figure 5.4).
Thus the transfer between modes does not have to be synchronized, offering a higher degree of operational flexibility.
Albeit, the technology can handle standard swap bodies or 20ˈ and 40' ISO containers; chassis and railcars gain extra weight as they have to be adapted and added with extra equipment.
Thanks to the ContainerMover 3000 system, no dedicated fixed infrastructure is necessary for intermodal load transfer, nor is there a need for extra personnel since the truck driver can handle the transshipment completely himself.

FIGURE 5.4 INNOVATRAIN'S CONTAINERMOVER 3000 CONCEPT (INNOVATRAIN'S, CONTAINERMOVER 3000 BROCHURE)

Removable adapted frames on the rail vehicle ensure that the ContainerMover 3000 can be operated with any intermodal flat wagon.

Despite the experience it is evident that it is difficult to persuade industry and operators to contribute to the development of general systems without an immediate return, they are normally willing to develop special systems suited to their own transportation needs.
Therefore, society might need to support the development of new intermodal systems with direct grants, both for research and development and demonstration projects.

5.6 INTERMODAL RAIL- SEA TERMINAL

Ports are the interface between two domains of freight transportation; while the maritime domain can involve vast geographical coverage as it is related to global trade, the land domain is related to the port's region and site location.
Ports handle the largest amounts of goods by accommodating transshipment activities and modern container ports commonly act as pioneers in automation and innovation of terminal operations.
In comparison with purely land based terminals, the operation and the information flows themselves are more complex: in port terminals the ITUs are commonly transshipped at least twice (ship to store and store to train). Ship-to-shore cranes, harbor cranes, straddle carriers, reach stackers and empty container trucks are the main equipment used for handling containers at both port and connected inland terminals.
A ship-to-shore rail mounted gantry (RMG) crane (Portainer) is a specialized version of the gantry crane allowed to move along the quay. Another type of crane which is common at large ports is the rubber tired gantry (RTG) crane, which is a mobile gantry crane used for loading and unloading of railcars and road trucks and for stacking containers. Several tracks can be covered simultaneously and containers can be stored at the side of tracks. RTG cranes are most effective when high numbers of railcars are handled systematically. RTG cranes can be moved between rail and yard operations.
However, whenever higher flexibility is required, the reach stacker is the preferred transshipment equipment as well as trailer is used for long distance movements within the terminal area.

Synthetically, in the terminal three typologies of activities are identified: i) movements onboard a vehicle (train or ship), ii) transfer from/to vehicles and stocking area, iii) waiting for the following

activity on-board ship or train or in the stocking area itself. New technologies and innovative operational measures can increase the performances in various phases.
The innovations are classified according to various elements of the terminal (layout, equipment, management, etc.) and time horizons (Table. 5.2).

TABLE 5.2 INNOVATIONS ACROSS COMMON STANDARD, INCREMENTAL CHANGE AND SYSTEM CHANGE FOR A RAIL-SEA TERMINAL. SOURCE: DICEA.

OPERATIONAL MEASURES			
	Common standard	**Incremental change (2030)**	**System change (2050)**
Handling typology	• Indirect and direct	• Mainly direct	• Faster and fully direct
Track operative length	• 550-850 m	• 750-1000 m	• 1000-2000 m
Working period	• Less than h24	• Partially h24	• Always h24
TECHNOLOGIES			
	Common standard	**Incremental change (2030)**	**System change (2050)**
Handling equipment in operative track	• Transtainer and reach stacker or forklift • Few systems for horizontal transfer	• Fast transtainer • Many systems for horizontal transfer	• Automated fast transtainer with moving train • Automated systems for horizontal and parallel handling
Handling equipment in storage area	• Transtainer • Reach stacker or forklift • Straddle carrier • Trailer (transport only) • Some AGV	• Fast transtainer • Automated transfer systems (e.g. container cross conveyor)	• Automated fast transtainer • Automated transfer systems (e.g. container cross conveyor)
Equipment, positioning and grab	• Manual • Manual with support technologies	• Manual with support technologies	• Automated
Equipment for vertical handling	• Spreader with twist lock • Spreader with grapple arms • Some intermodal spreader (grapple arms and twist lock)	• Many Intermodal spreader (grapple arms and twist lock) • Intermodal complex spreader (multiple ITU handled)	• Intermodal complex spreader (multiple ITU handling)
ITU/Vehicle identification and documentation exchange	• Manual control	• Manual control • Automatic control (automatic gate)	• Automatic control (automatic gate)
Security control	• Rare	• In most terminals	• In all terminals
OPERATIONAL MEASURES + TECHNOLOGIES			
	Common standard	**Incremental change (2030)**	**System change (2050)**
Locomotive	• slow with loco exchange (electrical-diesel)	• Fast with loco exchange (e.g. automatic coupling)	• Fast without loco exchange

5.7 Rail-rail freight terminals (marshalling yards)

This terminal typology is generally characterized by different groups of tracks. The trains are received in the arrival group, where the wagons documents are checked. The trains are split into groups of wagons, according to their final destination; the line loco is decoupled while the hump loco takes place behind the groups of wagons to shunt. The wagons are then pushed over a hump in a direction group, where they are braked using hump retarders placed along the tracks, finally reaching direction sidings where they are cumulated to reach the critical mass for a departing train. In this group checks on trains documents and wagons are performed, the line loco is coupled to the wagons, the brakes are tested and the train is ready to depart.

Systematic approach to functional requirements for future freight terminals, Transport Research Arena, 2014). The main phases are represented in Figure 5.5; to each phase are corresponding:

- Layout elements: number and typology of tracks groups, number and length of tracks in each group, presence of the hump, etc.;
- Operative rules: wagons speed limits, directions of traffic, groups of wagons weight and length, etc.

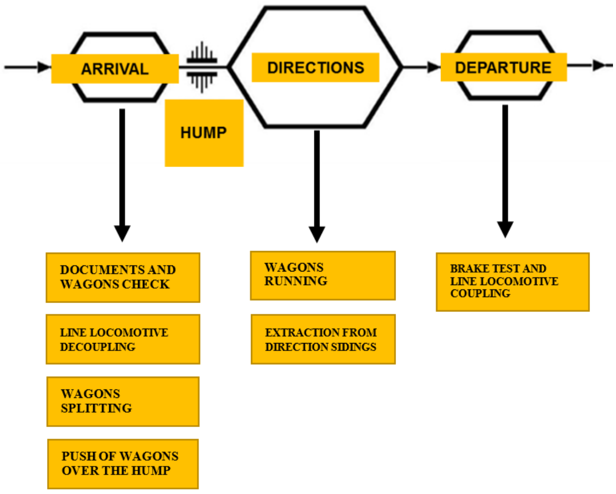


Figure 5.5: General scheme of a marshalling yard, with process in arrival and directions yards

New technologies and innovative operational measures are affecting different phases and can increase the performances of the station. The innovations are classified according to various elements of the terminal (layout, equipment, management, etc.) and time horizons (Table. 5.3).

TAB.5.3: INNOVATIONS AND COMMON STANDARD, INCREMENTAL CHANGE AND SYSTEM CHANGE IN A MARSHALLING YARD. SOURCE: DICEA.

TECHNOLOGIES			
	Common standard	**Incremental change (2030)**	**System change (2050)**
Brakes	• Manual controlled rail brakes • Automatic controlled track brakes	• Automatic controlled track brakes	• Automated brakes on wagons
Wagons speed regulation	• Braking based process	• Automotive wagons • Carried wagons	• Automotive wagons
Wagons coupling / decoupling	• Manual coupling	• Manual coupling • Automatic coupling	• Automatic coupling
Locomotive propulsion	• Diesel	• Diesel • Duo propulsion	• Duo propulsion
Locomotive driving	• Diesel	•	• Duo propulsion
OPERATIONAL MEASURES + TECHNOLOGY			
	Common standard	**Incremental change (2030)**	**System change (2050)**
Locomotive	• Diesel with driver	• Diesel + Duo propulsion • With driver + Driverless	• Duo propulsion • Driverless

5.8 AUTOMATION OF MARSHALLING YARDS

Further automation of marshalling yards (see Figure 5.6) may include; radio-controlled hump-locomotives, primary hump and secondary-retarders, piston retarders in the sorting tracks, wagon-movers, movable stopping devices and automatic brake test equipment. Complemented with an IT system to control all movements and an advanced planning system, marshalling can almost be done automatically.

Another trend which can be seen as contradictory is to introduce shunting areas without a hump. The fact remains that wagon load nowadays include more wagon-groups than single wagons and that radio-controlled locomotives makes it relatively easy to handle. Therefore the need of complicated hump yards has to some extent decreased.

New network strategies exist, which mix full train loads and single wagonloads to achieve a unified system based on the blocking principle. This system looks at the conventional traffic as dynamic wagon blocks that are susceptible to being coupled and decoupled. The new system is meant to increase the capacity of the trains and the frequency of the service by coordinating the timetable and the booking system better by using sophisticated IT systems.

5.9 AUTOMATIC COUPLERS

The ultimate solution is to introduce automatic couplers so the wagons can be coupled and decoupled automatically. The process will demand a minimum of staff and not be so dangerous for the workers. If this also is radio-controlled there will be further cost savings in the operations and it will also widen the market for wagonloads through more efficient operations on sidings and stations.

An advanced idea which do not exist in reality yet is to have self-propelled wagons which can operate themselves shorter distances on sidings or on marshalling yards.

Figure 5.6 Automation of marshalling yards. Source: A.C. Zanuy 2014.

5.10 ROLL ON ROLL OFF TERMINALS FOR TRAILER HANDLING

Most trailers today are not designed to be lifted onto a railway wagon. The trailer market is in practice therefore very limited even at conventional intermodal terminals that have lifting equipment. It is therefore a great advantage if trailers can be rolled onto the wagons. Solutions where trailers do not need to be lifted but can be rolled on and off the wagon can thus widen the market considerably.

A traditional solution is the “rolling highway” commonly used for example in alpine passes. This solution is very costly, partly because the entire truck including the driver has to be loaded and partly because the railway wagon itself is expensive to buy and maintain.

There are many different technical solutions for loading trailers, some of them tested on the market, some of them planned. One example of system in service is the Modalohr system in France, see figure 5.7. It has the possibility to handle non-liftable trailers, however it need a rather complicated wagon and also a special ramp at the terminal. Another project is Trailer Train which look alike the system used in US for trailers on flat cars (TOFS). This only needs a ramp at the end of the train but a lower wagon and a high loading gauge. By this it is also possible to achieve high length utilization of the train because the trailers can be packed very densely on a rake of flat cars, see Figure 5.7.

The cost of handling units with a reach stacker at conventional end-point terminals is approx. 30 €/unit. At a liner traffic terminal with forklifts, this may be reduced to 15€/unit if the train driver drives the forklift but is restricted to 20 ft containers or swap-bodies. Approximately the same cost can be calculated for the ContainerMover system with the transfer system on the truck. With a horizontal transfer system like CCT the cost is estimated to be around 10 €/unit. Handling a trailer with Megaswing or Trailertrain that do not require a special terminal costs roughly the same, see Figure 5.7.



Figure 5.7: Most of the trailers are not liftable, therefore roll-on off/roll on technique is an alternative. Left: The Modalor system with special ramps on each wagon. Middle: Trailer Trains only need a ramp at the end of the train but a low wagon and a high loading gauge. Right: A Trailer Train are more space efficient than a train with pocket wagons. Source: KTH.

5.11 Fully automated terminals

Fully automated terminals are already in service in ports and also for intermodal traffic in Germany. So far these terminals are rather complex and expensive and can only be used on very big terminals. Rail requires automated terminals for smaller demand so intermodal service can be profitable on shorter distances and frequent services.

Figure 5.8 shows an example of measurable achievements which is estimated for a future system for horizontal terminal handling in combination with liner trains as follows:

- The cost for terminal handling of a unit will be reduced by approx. 60%
- Break-even point for inter modal will be reduced from 500 km to 300 km

The terminals will be cheaper and smaller so it will be possible to have more terminals which will reduce the distance for feeder transport and widen the market further

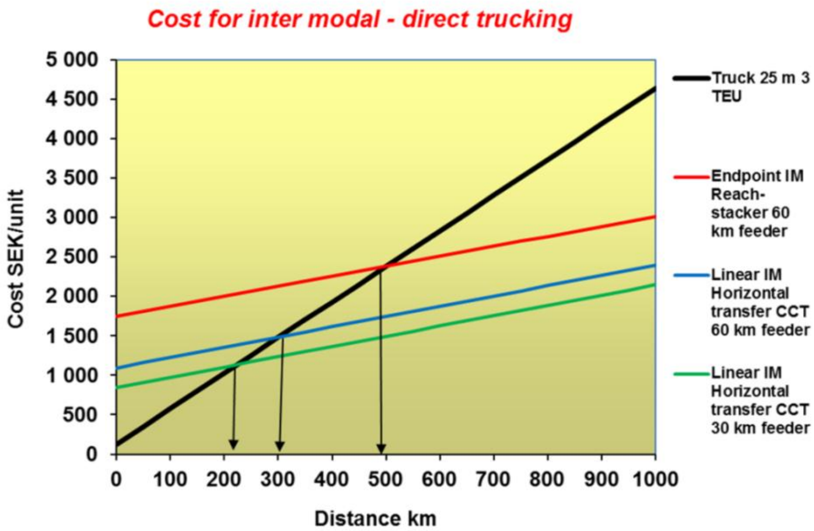


Figure 5.8: Cost of conventional intermodal traffic and intermodal traffic with horizontal transfer of CCT type and with regular traffic with shorter feeder distances. Source: Roadmap for development of rail and intermodal freight transportations, KTH Railway Group Report 2013

6 Operations

6.1 Traffic & operational development

6.1.1 A system approach

Development of the future system must have as its starting point optimised freight transportation on the basis of a system view of the railways: including the customer's transportation needs that put demands on the wagons – the wagons are coupled together into trains where available tractive power is taken into account – the train that utilises the infrastructure with a certain performance along a link and ultimately in a network from origin to destination. The intention is to analyse the railway system from its actual performance today to what is planned for the future and what is optimal when considering the system as a whole. The principle of the optimisation is shown in Figure 6.1.

6.1.2 Optimisation of trains for different transportation needs

As regards the freight transportation system, development has technically speaking always been incremental. Performance has gradually improved but it is the tractive power – the locomotives – that has often determined the standard of the trains and the infrastructure. The trains in Europe are dimensioned according to tractive power, the braking system and the infrastructure standard depending on inclines, track length at stations and other physical limitations. Much of today's freight train system and technology is based on a normal 3-4 MW locomotive, in Sweden, the Rc locomotive, that was introduced in 1968. This means trains of approximately 1,650 gross tonnes and a length of 630 metres.

Modern locomotives have a tractive power of 5-6 MW and there is technology available to operate longer, heavier trains. The USA, for example, has trains of between 2,000 and 3,000 metres in length with radio-controlled locomotives distributed along the train. One important question is what the standard tractive power in Europe will be in the future with the next generation of locomotives – and what trade and industry will need.

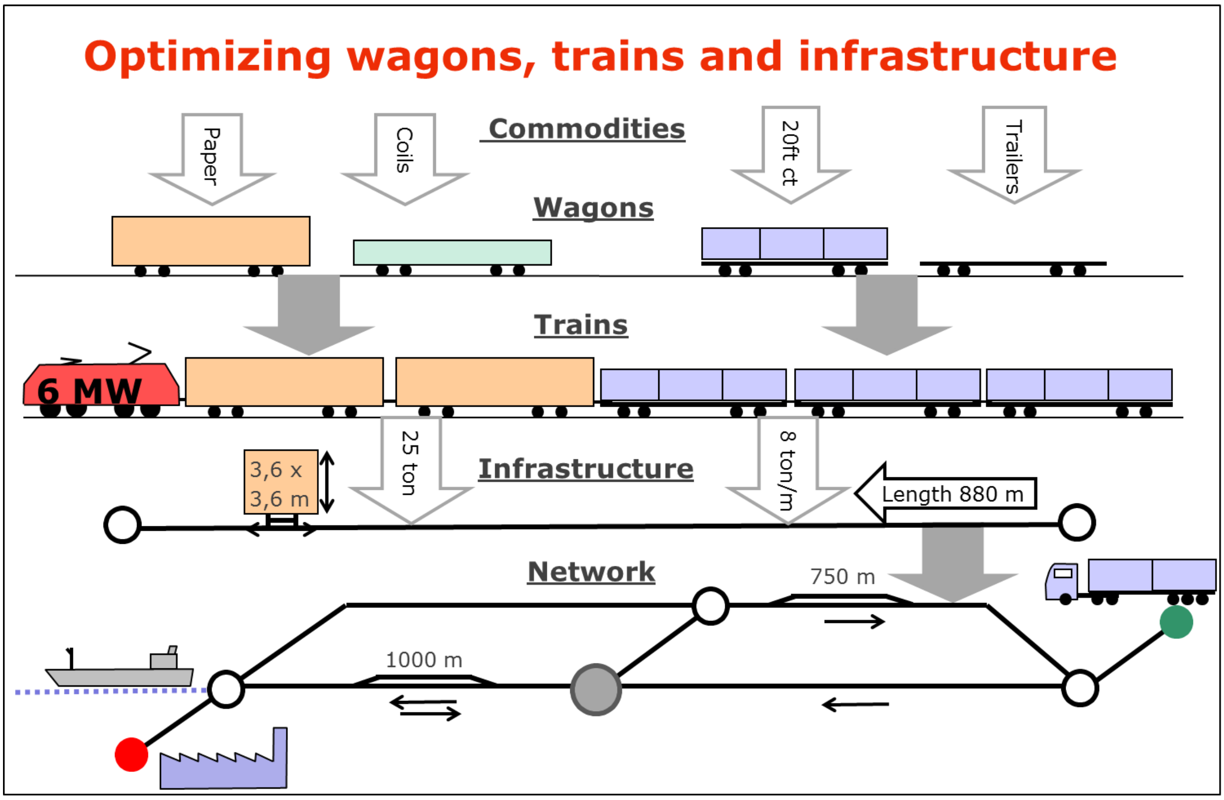


Figure 6.1: Principles for optimising wagons, trains and infrastructure. Source: Roadmap for development of rail and intermodal freight transportations, KTH Railway Group Report 2013.

6.2 Development of traffic systems & products

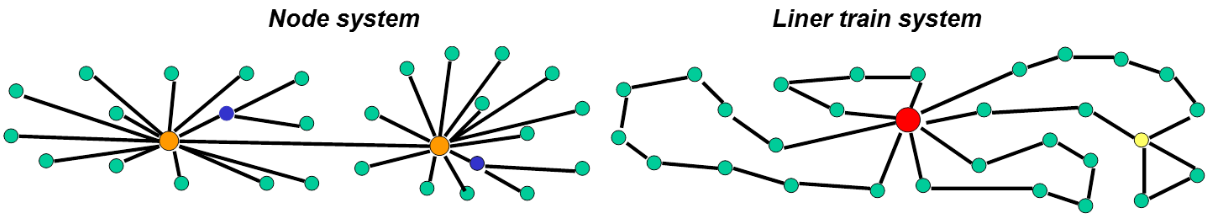
6.2.1 Liner trains instead of node systems

Instead of a conventional hub and spoke system, a system of liner trains has been proposed (Nelldal et al 2005), where the trains run on a main route and wagons are picked up and dropped at the stations along the way. In many cases, feeder trains can be avoided and the wagons no longer need to be shunted at a marshalling yard and hauled by feeder trains. The liner train system can also be combined with a hub system so the trains can exchange wagons at suitable places, and because marshalling yard can handle more relations.

The left diagram in figure 6.2 shows a conventional wagonload system consisting of 30 nodes of which two are marshalling yards and two are secondary nodes. To link the system's terminals, at least one long-distance train in each direction is required every day, between the marshalling yards, and 26 feeder trains in each direction. This makes a total of 56 train movements a day. In addition to the liner locomotives, terminal locomotives are needed at most terminal nodes. The right diagram shows a liner train system where the trains pick up and drop wagons along the route. The system consists of 5 loops, 4 of which meet at a central marshalling yard, and one meets another at a local node. This system needs only 10 train movements in each direction each day to cover the same terminals as the node system.

A calculation shows that transportation costs are reduced by 17% in the case of wagonload traffic. If duo locomotives are used, the transportation costs can be reduced by a further 5%. With a duo locomotive, the same locomotive can be used for shunting and for long-haul traffic. The trains do not then need to change locomotives to enter a terminal.

Figure 6.2: Conventional hub and spoke system (left) and liner system with the same market (right). Source: Efficient train systems for freight transport - A systems study, KTH Railway Group 2005.



6.3 RAIL PRODUCTS FOR DIFFERENT MARKETS

In section 2.2 it was discussed that market requirements vary for different commodities. Distribution shipments of finished goods to warehouses or direct to the consumer can be divided into two groups. One group has the same transportation time requirements as the basic products but demands higher quality, for example in terms of handling, cargo security, temperature, etc. and has a more disparate structure. The requirement for overnight transport is more precise and often concerns the period between 5 pm and 7 am.

Lastly, there is an express freight market, e.g. for post and spare parts, where the requirements coincide with those of the passenger trains, i.e. high average speed, high accessibility during most of the day (high frequency of service) and broad geographical coverage of the market. Compared to normal freight transportation, the price levels in this market are relatively high.

There has always been an effort to make all modes more efficient by incremental changes to gain customers. Sometimes big steps are taken that affect the market substantially. Especially important for rail is competition from longer and heavier trucks which is proposed in Europe.

- In Germany and other countries from 18 m truck to a longest 25,25m mega truck and gross weight from 40-44 tonnes up to 60 tonnes
- In Sweden from 25.25 m to at longest 34 m truck and gross weight from 60 up to 90 tonnes

The positive effects of this on industry are obvious if the normal EU 40-tonnes truck is compared with the Swedish 60-tonnes one. Transport cost per ton-km in Sweden is about 30 %.

In the 1990s gross weight of Swedish trucks increased from 51.4 to 60 tonnes led to a 20 % decrease in ton-km rates. This had the following negative effects on Swedish rail haulage:

– The truck could compete even more effectively with the train also for long distance hauls and for even larger freight volumes, see figure 6.3.

– The market price of general haulage dropped, which put great price pressure on rail haulage.

– This led to a drastically deteriorating profitability among rail operators, both state and private ones.

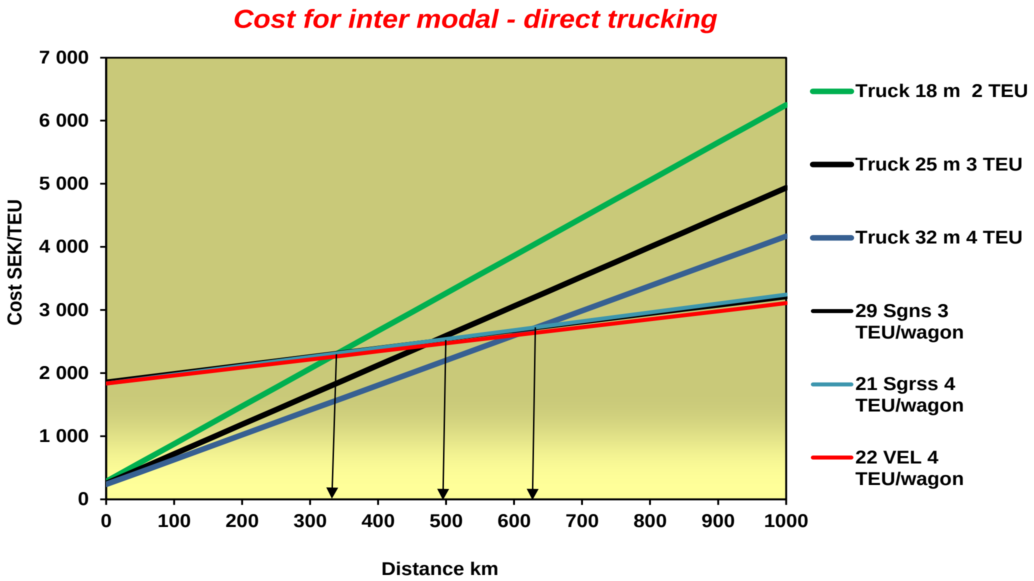


Figure 6.3. Transport cost per tonne for an intermodal transport with 20 ft containers on different wagons compared with an 18 m EU truck, a 25.25 m Swedish truck and a 32 m Swedish experimental truck, calculated in Swedish costs. Source: KTH calculations in VEL-wagon 2012.

One major reason why such a change in the break-even point should affect the railway market share so much is the rank-size rule: the longer the distance the smaller the volume. The large freight volumes are in the short-distance sector. Even if longer distances account for a great deal of the transport work effort, the less-than-500-km hauls account for two-thirds of all long-distance hauls.

In the short term longer trucks are positive for the industry because transport prices decrease. But in long term, if the rail system has to shrink to survive, the competition between modes will be reduced and prices could be higher. This is especially a problem if the whole wagon-load system is abandoned.

Also the environmental effect is positive in the first step when two trucks can transport as much as three trucks. In the next step, when rail market share decrease, the total energy consumption and GHG for transportation can increase.

7 Summary and Conclusion- A new interoperable rail freight system

This report aims to study and design new concepts for a modern, fully integrated rail freight system to provide efficient network –based services based on principles for seamless logistics and hence meet the requirements of 2030/2050. For this C4R has studied the findings and conceptual system designs achieved in different EU collaborative rail freight research efforts to build a new interoperable system for rail freight incorporating a new generation rail freight vehicles, seamless freight transshipment, and interoperable rail networks.

The progress in rail freight system does not simply rely on progress in one element e.g. wagon or network or terminals. It must incorporate progress achieved in different elements but in an integrated approach so that total train systems are achieved. Improvements are required that will allow the application for better paths on the network impacting positively on the use of assets, total driving costs, the smoothness of transfer at hubs or marshalling yards. New types of wagons (e.g. flexible) as well as the use of new material for its construction can impact positively on the available payload, the usable length and the usable volume on a given train.

7.1 The freight terminal as a reliable and effective transhipment point

Previous research suggests that unreliability of rail freight services can be largely attributed to terminal transshipment (in)ability and thus the future terminals must meet the requirements so that it contributes to achieving reliable, efficient and effective freight supply chain. Towards this new terminals need to meet the following operative features;

7.1.1 Transit time

Divided into several components that represent all operations within the terminal, e.g. time between the moment when load unit is ready for transport and the loading vehicle exit from the terminal; time between the last admitted arrival at terminal entry gate and the real departure time of train; time for documents and handling procedures. The main aim of the future terminals is the shortest time factor to avoid that the terminals act as bottlenecks of the freight supply chain.

7.1.2 Reliability

Represents the effective closeness of terminal operations compared to the reference or promised time. Future terminals will increase the performance of this parameter, because it will have to deal with high flows of goods including unitized ones and means of transport. This parameter will be top priority among the major rail freight operators in the choice of the terminals.

7.1.3 Flexibility

Representing the easiness to adjust the system to unexpected changes (e.g. high volume) in logistic requirements and related to two main characteristics: the terminal size and the equipment for ITUs handling (intermodal terminals) or for rail freight wagons (marshalling yard). In future, terminals will be required to process large volumes of freight in short notice, thus they must be able to receive and handle these volumes in terms of vehicles seen and diversified cargo units.

7.1.4 Monitoring and security

The future terminals must be a partner in the total transport and supply chain and be connected with information system facilitating monitoring of the location and status of goods throughout the freight supply chain arriving trains and trucks. Malfunctions and poor maintenance of terminals can significantly reduce the systems´ capacity. To reduce the occurrence of such situations and to improve system safety, condition monitoring and condition-based maintenance technologies.

7.2 Intelligent and high speed networks

The recent addition of big data analytics in transport may see the further development of intelligent systems for example in track and trace, the knowledge of all movements on the network through big data analysis will allow an updated Estimated Time of Arrival in case of delays. It will be possible for the connected train to forward information; to the ECM of the wagon declaring its effective work, about the status of its critical components for maintenance purposes; to the shipper about the status of the cargo, to the Infrastructure Manager on the progress of the train for efficient train management purposes and to terminals on the updated ETA to prepare operations.

Increased top speed of rail freight trains moving on the infrastructure would definitely increase capacity to some extent, however it is important to consider what kind of capacity would be increased by higher top speeds, rail freight wagons constructed for considerable higher speeds than what is "standard" today would most likely have lower pay loads, transport cost per tonne-kilometres would increase, as a consequence the high value cargo transported on rail might increase while the low value cargo transported might decrease. A theoretical increase in the supply of available train paths need to be evaluated against the risks of worsening the total pay load of a faster freight train.

Activities aiming towards increasing the average speed of the freight trains is most likely a more realistic and favourable path to choose in order to improve the capacity of the railway network. This opinion is supported by both the TEN-T recommendations and a transport market study (TMS) made in 2014 by ETC Transport Consultants GmbH on behalf of the ScanMed Rail Freight Corridor.

This survey stresses that the average speed is more important than the maximum speed and that the last mile very often is the determining factor with regards to overall transport times. Speed restrictions are in place on certain sections and even though higher speeds would be technically possible a constant max of 100-120 km/h would be sufficient and less costly.

7.3 Future wagons

More recently, specialized wagons are built for specific commodities or special types of transport, with specifically optimized designs and technical characteristics. This is true for bulk traffic, dangerous goods, steel products, finished new vehicles, combined transport of containers, swap bodies and transport of semi-trailers (vertically or horizontally handled) or articulated lorries. New wagons generally built for specific traffic are intensively operated, on these wagons progress may also occur on sub components like the bogies, braking system of the wagon, coupling system in order to reduce the LCC and to increase the payload, or the usable length or volume.

The rail freight business has to come up with new innovations to meet the customer requirements by developing, for example, flexible wagons. The main focus should be to improve efficiency, reliability and to contribute to a decreased transport costs from the *initial* place of loading to the final destination. Potential improvements in wagons include improved wagon design capable of carrying high cube (i.e. 45ft containers) and/or higher number of containers, with EP brakes facilitating faster acceleration & braking (similar to passenger train characteristics) and EOT device to reduce the duration of safety checks prior to departure.

7.4 OPERATIONS OF INTEGRATED RAIL FREIGHT SERVICES AS PART OF THE LOGISTICS CHAIN

Integrated door-to-door, reliable and competitive are the major characteristics of an integrated logistics chain (Islam, 2014) and to compete, rail freight operators will have to offer a service along this line. A few options can be considered to offer such a service. Firstly intra-rail premises to premises service option where rail operators offer services to the traditional big customers such as power plant for transporting coal, transport of iron ores for steel plant and its outputs etc. For this type of service, the operation of SWL plays an important role. However work by (Consultants, 2014; Woroniuk, Marinov, Zunder, & Mortimer, 2013) have revealed that the volume of SWL is declining. The cause of this decline are identified by recent studies such as SEPCTRUM (Jackson, Islam, Zunder, Schoemaker, & Dasburg, 2014) and D-RAIL (Islam, Jackson, Zunder, & Burgess, 2015) while the literature also suggests that there is a significant change in cargo type, customer needs and customer types.

A significant volume of freight movements are generated by small and medium size enterprises SMEs (Islam, 2014) that currently are not under the operational radar of rail freight operators. To meet the modern customer demands, rail freight operators will have to adapt to the market needs. The following model for an integrated rail freight service was proposed by (D. Islam, 2014):

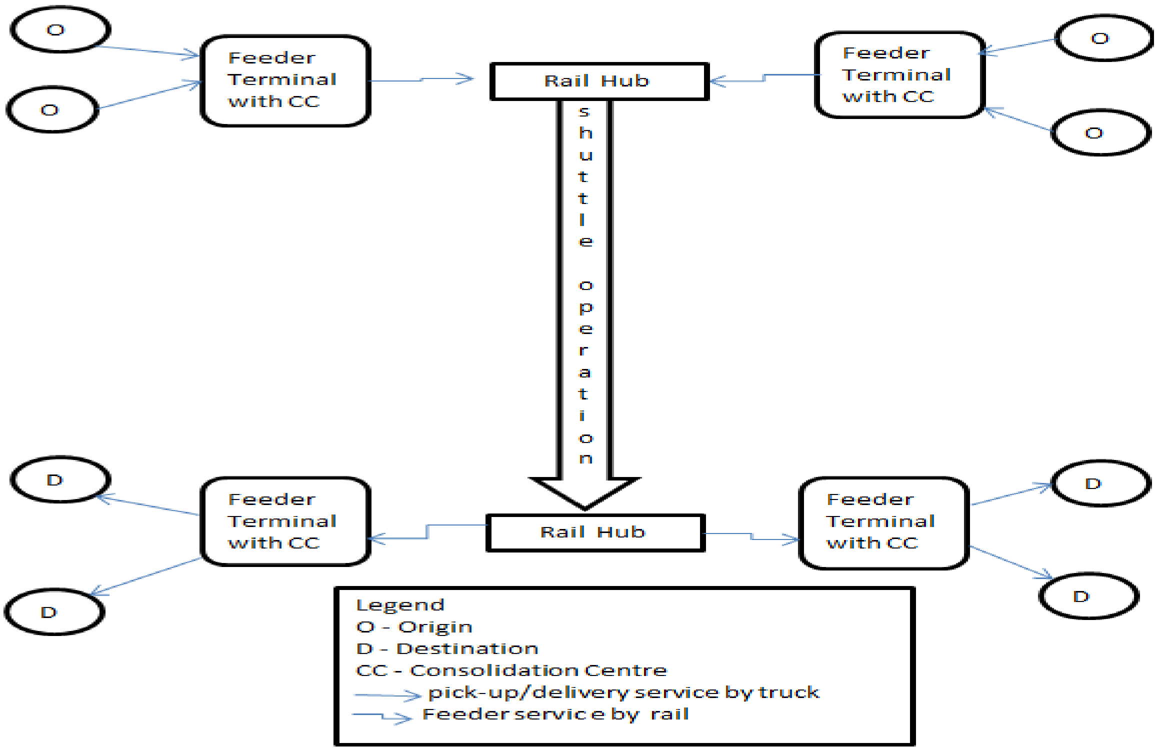


Figure 7.1 Integrated multimodal rail freight (with feeder and shuttle) service operation (Islam, 2014)

7.5 Conclusions

In this report C4R aimed to study and design new concepts for a modern, fully integrated rail freight system, which meets the requirements of 2030/2050. The European Commission set ambitious targets for modal shift of goods, a high speed network and upgrade on freight lines to 22.5 axle load, 740m train length and 100km/h line speed. C4R has investigated four components of an integrated freight system; vehicles, network, terminals and technical and operational aspects where the current state of the art is identified for each and the changes necessary to achieve the EC goals.

Potential vehicle improvements included;

- Wagon design which can mix 45ft containers and increase the total number of units.
- EP brakes, to generate better train manoeuvrability
- End of train device to reduce the duration of safety checks prior to departure

Potential network improvements to increase capacity included;

- Increase in train length
- Increase in axle and meter load
- Increase in average speed
- Increase in loading gauge

For Rail-Road, Rail-Sea and Rail-Rail, operational and technical measures have been identified to achieve both an incremental (2030) and system change (2050).

While for technical and operational aspects potential improvements include;

Short-term measures which aim to use existing infrastructure and vehicles better without major investment;

- Load more freight on existing wagons by using a higher loading gauge.
- Operate heavier trains by utilising the tractive power of modern locomotives
- Standardise braking rules and tables that make better use of possible performance
- Operate faster freight trains (in the range of 100 to 120 km/h) to obtain more train paths
- Operate longer trains on the major TEN-T corridors and at special times where possible
- Establish a freight database for groupage to utilise capacity better
- Secure sufficient quality in international freight corridors

In the medium to long terms there are further measures that require closer analysis and sometimes investment:

- Secure capacity in international freight corridors
- Optimisation of wagons for different customers' needs with larger loading gauges and higher axle loads
- Heavier trains with locomotives that have higher static adhesive weight
- Longer trains according to the market's needs on special freight routes after careful planning and additional investment
- Lighter wagons with lower tare and higher payload
- Introduce incentives for track-friendly running gear and for better brakes and improved braking performance
- Introduce automatic couplers to reduce shunting costs and widen the market

Alongside meeting the above mentioned technical improvements, the study recommends the following steps:

- Operators will conduct a combination of 'terminal-to-terminal' and 'door-to-door' service operations;
- Operators must build partnerships with other modal (e.g. road) operators and freight forwarders or 3PLs to include all types of customers including SMEs and customers of non-rail (low density high value) cargo.
- Operators need to make use of consolidation centres that facilitate bundling of cargoes, in particular for urban areas which are location of majority of the European freight transport customers (Islam, 2014).

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9 Appendices

9.1 Appendix 1

Code and definition of goods typologies (NST 2007)

GT01	Products of agriculture, hunting, and forestry; fish and other fishing products
GT02	Coal and lignite; crude petroleum and natural gas
GT03	Metal ores and other mining and quarrying products; peat; uranium and thorium
GT04	Food products, beverages and tobacco
GT05	Textiles and textile products; leather and leather products
GT06	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter, etc.
GT07	Coke and refined petroleum products
GT08	Chemicals, chemical products, and man-made fibres; rubber and plastic products; nuclear fuel
GT09	Other non-metallic mineral products
GT10	Basic metals; fabricated metal products, except machinery and equipment
GT11	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment
GT12	Transport equipment
GT13	Furniture; other manufactured goods n.e.c.
GT14	Secondary raw materials; municipal wastes and other wastes
GT15	Mail, parcels
GT16	Equipment and material utilized in the transport of goods
GT17	Goods moved in the course of household and office removals; baggage and articles accompanying travellers; motor vehicles being moved for repair; others.
GT18	Grouped goods: a mixture of types of goods which are transported together
GT19	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.
GT20	Other goods n.e.c.

9.2 Appendix 2- List of meetings

Date	Physical/ tele/online	Nature of meeting
16/11/2015	Physical, Newcastle upon Tyne, UK; hosted by UNEW	Kick off
23/2/2016	Online/tele progress meeting hosted by UNEW	Progress meeting
7/04/2016	Online/tele meeting hosted by UNEW	Progress meeting