Longer trains
Facts & Experiences in Europe

Results of the CER working group on longer and heavier trains

May 2016

CER aisbl - COMMUNITY OF EUROPEAN RAILWAY AND INFRASTRUCTURE COMPANIES
Avenue des Arts, 53 - 1000 Bruxelles | T: +32 (0)2 213 08 70 | F: +32 (0)2 512 52 31 | @CER_railways | E: contact@cer.be | www.cer.be

Table of contents

1 Introduction and definitions

Summary

Longer trains are one way to improve the effectiveness and efficiency of the rail freight system, allowing more efficient operation and an increase in transport capacity. Railway undertakings (RUs) see longer trains as a key approach to competitive rail freight, whereas infrastructure managers (IMs) could face a major investment effort. A win-win situation for both RUs and IMs has to be established as the necessary investments are mainly on the infrastructure side. Maximum allowed lengths of trains vary in Europe. Infrastructure planning has to consider additional elements for necessary length of tracks.

The main aim of this paper is to develop an overview about the current activities of **trains longer than 740 m**, as agreed by CER and EIM infrastructure managers at the High Level Infrastructure Meeting in Frankfurt in 2011. This document explains the technical, operational and economical aspects of longer trains as well as providing an overview of experiences and solutions implemented in different countries.

Rail is the *greenest* transport mode, the most efficient in terms of land-use, and the most cost-effective when managing large flows of passengers and goods. Nevertheless the overall situation of the railway system in Europe, and especially the rail freight system, is not satisfactory. Only a few rail freight companies make profit and the modal share of the EU rail freight market in comparison to other transport modes declined from 18.5 % in 2000 to 16.2 % in 2010. [1] Additionally, costs have become the most important criteria for freight customers since 2009. [2]

Despite this situation, freight volumes are expected to increase more than 80 % and passenger volumes about 50 % by 2050. [3] This increase in freight traffic will be especially visible in combined traffic. The railway system, including RUs (RUs) and IMs (IMs), has to adopt new measures in order to avoid further losses in the freight modal split and benefit from the growing transport market. Longer trains are one promising approach to strengthen the market position of the railway system, as far as Quality of Service is preserved. Enabling the operation of longer trains is a significant shift for the railway system, implying the adaptation of infrastructure, technical equipment, railway operations and many other changes that need to be analysed in detail. This paper consolidates the discussions and the exchange of information between the experts of the CER sub-working group on longer and heavier trains. It is a further development of the CER principle position paper from 2011 [6].

It only deals with the approach of longer trains, defining longer trains as trains with a total length of more than 740 m (see chapter 1.4). Increasing the maximum axle load to allow heavier trains is a different approach that should be discussed separately.

1.1 Advantages and potential of longer trains

From the RU point of view, the operation of longer trains improves the productivity of rail freight traffic. The amount (volume) of goods that can be transported by a single train can be increased by 35 % (1,000 m train) and up to 103 % (1,500 m-train) in comparison to a train of 740 m.

- **Quality of service**

Quality of service is the baseline for increasing train length. End to end and system approach as well as long term traffic growth planning is necessary to assess the feasibility of increasing train length while maintaining a similar level of Quality of Service.

- **Efficiency**

From the RU prospective, longer trains allow a more efficient deployment of resources (train drivers, possibly traction units) for a given hauling capacity. Some of the expenses for operating a freight train increase with the length of a train (e.g. energy costs, marshalling expenses) while others can be considered as independent from the length (e.g. expenses for locomotive and train drivers). The increased productivity and thus the increased competitiveness are essential advantages for the RUs at a given Quality of Service level. It leads to a better positioning on the rail freight traffic market and can help to increase the intermodal market share of the railway system.

- **Capacity**

In the railway system, capacity is defined as the number of trains that can be operated on a track in a given time at a defined level of operational quality. On one hand this *track capacity* will decrease to a certain extent depending on the surrounding traffic and on the train configuration as a longer train will occupy the infrastructure (block section) for a longer time.

On the other hand, the *transport capacity*, defined as the amount of goods that can be transported on the track in a given time, increases. As the aim of implementing this new functionality is to improve railway transfer mode, one can expect that this can allow for new traffic as far as the expected QoS is met; given a constant amount of goods, this amount can be transported with less trains and under some conditions, this can allow for the usage of the free capacity for other trains.

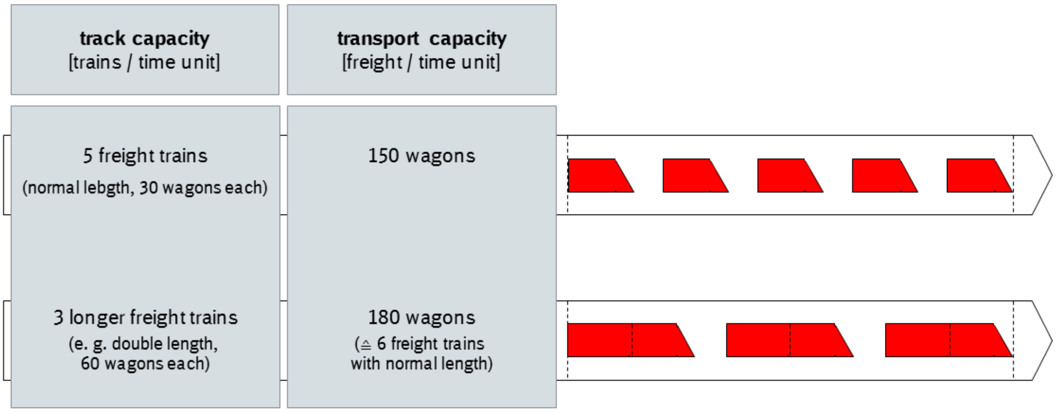

Figure 1: Alternatives of line occupancy (example) (source: DB Netz AG)

There are two different kinds of long trains:

<u>one locomotive with more wagons than standard</u>

> The first one consists in adding wagons within the traction capability of the locomotives. In this configuration, the train is heavier and less reactive, what can create adverse conditions in heavy traffic situations. Depending on the load of each wagon, the traction capability can be reached before the length limitation.

<u>two locomotives connected over remote control</u>

> The second one consists in connecting two trains with one locomotive on the head of the train and one in the middle of the train. A remote control system between the first and the second locomotive is needed.The train reacts more or less like a single train, is better adapted to heavy traffic conditions, but the locomotive has to be upgraded with new equipment. Connecting two trains with one locomotive in the front and one in the middle over remote control is not regularly used yet and has to be studied.

The marketable capacity effect will also depend on the timetable construction. In a fixed and very dense timetable slots might be too small for longer trains.

The capacity is also defined by the yard specifications. The yards must be able to receive longer trains easily. If a long train needs to wait on the main tracks for shunting operations before parking in a yard, the capacity will decrease even more.

In Germany, the study *GZ 1000* [4] provided a first estimate of the capacity effect for 1,000 m trains in a section of the German part of the Rhine Alpine freight corridor.

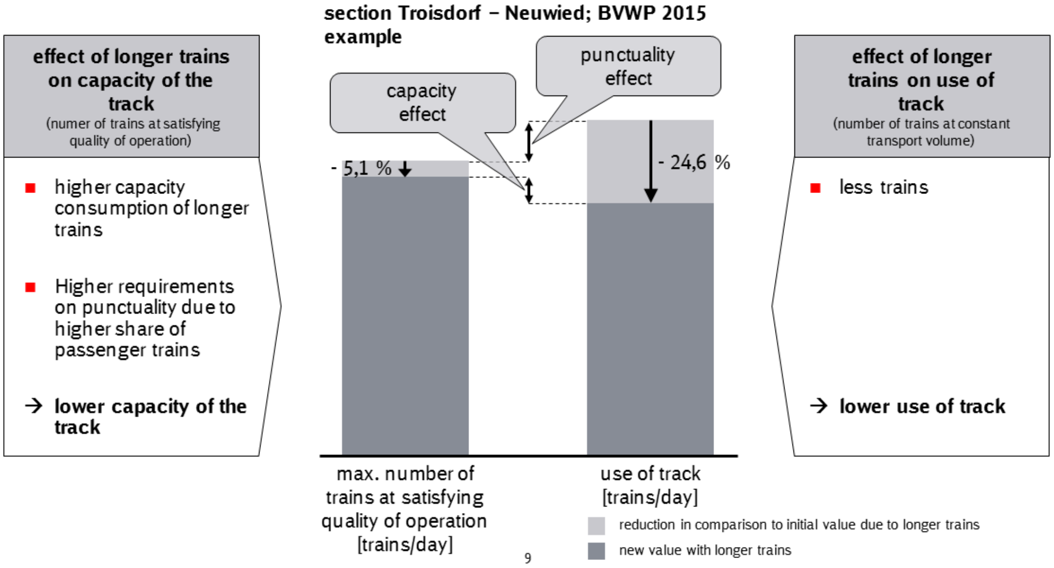

Figure 2: First estimate of capacity and punctuality effect for 1,000 m trains on a section of the Rhine-Alpine Corridor (source: DB Netz AG)

It is possible that a *double train* (2 x 750 m) needs less space on the network than two normal trains (750 m), which means more capacity for the IM; however, this is not the sole criteria to be taken into account; long trains have to be properly managed so as not to interfere more than others with the surrounding traffics: garage tracks should eventually be built, shunting yards should be thought to receive those trains as well as shorter trains, and electrical power stations adapted if needed along the path.

- **Shift towards rail**

Quality of service is the key success factor to help shifting transport from road and waterways to railways. Under this condition, the effects of a more efficient railway operation and the increase in the transport capacity both strengthen the railway system.

1.2 Longer trains points of attention

Allowing for longer trains than currently admitted on a network can have an impact on both mobile and infrastructure components of the railway system. It can also raise traffic management issues, which need to be addressed.

The Infrastructure is generally dimensioned to allow for a defined maximum train length; allowing longer trains therefore implies to check if modifications of the infrastructure are not needed, and if the quality of service is then likely to be guaranteed at the same level for all traffics.

Modifications of the infrastructure may impact power stations capacity, catenary, security installations configurations, signalling systems, shunting yards[1].

On the locomotive side, security speed control systems could also be affected by lengthening the trains, as some system do not allow for overpassing a certain dimension.

The longer the train, the higher the price (and feasibility) of the modification has to be questioned. Sometimes, it is possible to allow for operational restrictions, instead of investment, but as this could increase hazard on the network, this should be carefully studied. For detailed information see chapter 4.

Also, network modifications should take into account the success of such an economical advantage for RU, and the fact that this train format could therefore become over time a standard; an acceptable situation for few long trains could become a difficult constraint when most of the traffic is at a length for which the network has not been originally conceived for.

In this kind of situation, flexibility can be a way to solve the problem, with, for example, authorisation given on certain sections of the network, at a certain time of the day; for this idea to become a reality, it is necessary to have double trains rather than single long trains, think the use of the network differently, and probably adapt regulatory rules. Path price can also be a way to control the number of long trains on the network.

In other words, longer trains up to 1.500 m are long term system projects.

1.3 Railway Undertakings' needs

[Input by freight operators represented in the CER Freight Focus Group]

The rail freight market is currently in a situation in which no more customers are able to send whole trains with a payload corresponding to the maximum traction capacity of the locomotive and/or the length limit of the network. So the market demand has to be differentiated in railway companies and transport customers.

The RUs (which are already under pressure to preserve their competitiveness) and particularly the combined transport operators must therefore find solutions to optimize the use of their means of production (e.g. locomotives, drivers) so as to increase their productivity.

Therefore, from the perspective of railway companies as users of railway infrastructure, the matter of train lengthening is highly important. It is the most effective operational and technical leverage to increase productivity in rail freight. For example, within

[1] Shunting yards are a part of terminals definition in EU regulation 913/2010 (Chapter 1, Art. 2(c)): 'terminal' means the installation provided along the freight corridor which has been specially arranged to allow either the loading and/or the unloading of goods onto/from freight trains, and the integration of rail freight services with road, maritime, river and air services, and either the forming or modification of the composition of freight trains; and, where necessary, performing border procedures at borders with European third countries.

Maschen-Padborg it is most important to note that since the 835 m trains were introduced on the line, the actual utilization of train length of this traffic improved by almost 20 %. It is most important because there is no other leverage with a similar impact on utilization and productivity, given that normal procedural measures contribute 2-5 % at best. Also, the effect is not specific to the traffic line Maschen–Fredericia; similar effects are expected on most other routes. Additionally, it is a fact that lengthening from 740 m to 835 m is just a light improvement compared to an increase up to 1,000 m or even 1,500 m. Those sizes will lead to much larger steps forward. The greatest potential is on main tracks (Rhine corridor and North-South-line in Germany, Luxembourg/Méditerrannée, North-East-corridor and North/South-West-axis in France, e.g.), but this form of production is supposed to be suitable on other sections as well. With respect to the goods, there are no restrictions, quite the reverse: longer trains lend themselves particularly well to the combination of different heavy goods.

SNCF Fret and DB Schenker Rail have already begun to modify the exploitation system by mixing single wagon traffic with complete trains in order to maximize the traction performance on the main corridors within the standard authorized train lengths.

In the view of transport customers, the main interest lies within the most efficient forms of production. The more efficient the production, the more likely it is to have the leeway to achieve both attractive prices for customers as well as improved earnings from the utility. With increased competitiveness of rail transport, railways could attract additional traffic which is currently transported via other transport systems due to today's cost structure (especially by road). The coupling of traffic from different customers to a 1,500 m train could be integrated into the commercial models of utility; coupling of traffic is already a standard practice in the context of car group concepts. Within the network traffic of the single car system, the problems due to trains not being assigned to a customer are eliminated. For large customers, such as in customer traffic, customized 1,500 m concepts can be developed. The same works for maximum train lengths smaller than 1,500 m. Even with a 900 m train follow less pronounced productivity gains, which are in the interest of both railway companies and transport customers.

1.4 Challenge: how to find a win-win situation for both RUs and IMs

Longer freight trains are expected to generate economic benefits, but they also require potentially heavy investments in infrastructure and possibly in the rolling stock equipment. Adaptations to infrastructure are needed for operating of longer trains (e.g. sidings with an adequate length, power station upgrade, shunting yard adaptation, security equipment configuration… see also chapter 6). They may also be necessary for safety reasons (see also chapter 5). The business case depends on the market potential, the operational concept and the necessary investments, and it should in any case be considered from a System point of view.

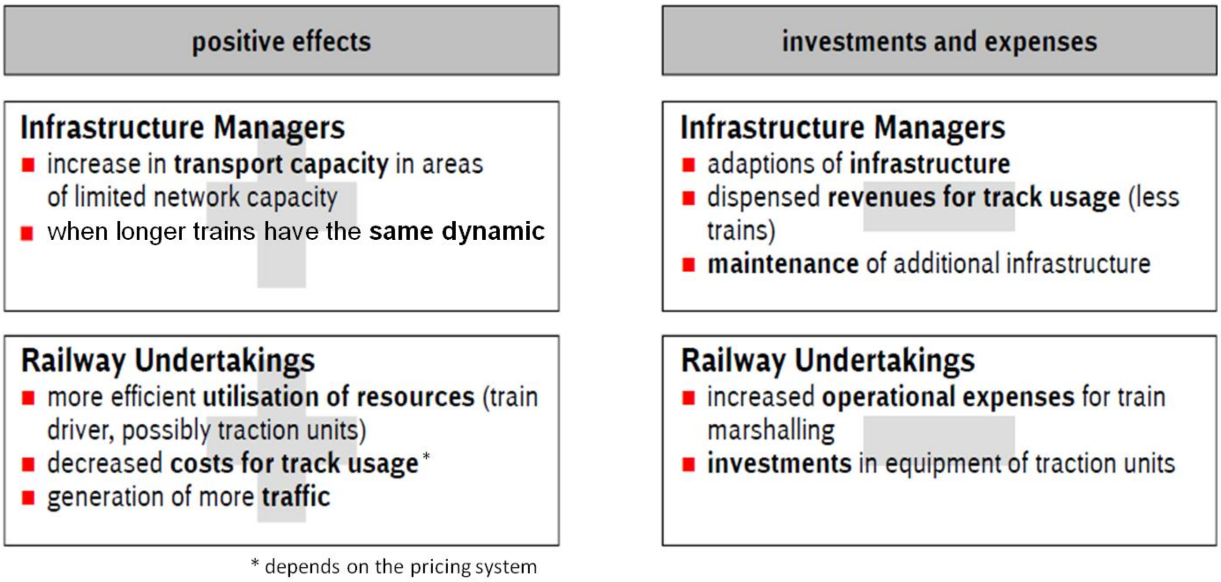

Figure 3: Economic effects of longer trains (source: DB Netz AG)

For the time being, pricing for the usage of tracks primarily depends on a price per train, which is not suitable when considering a level of long train traffic above a given threshold, and do not take into account the level of investment required. Moreover, should the pricing favour long trains, the impact on the number of long trains, hence the level of special equipment needed, could be important (for example side tracks, shunting yard equipment or configuration, power station upgrade…). The following table shows an example of a price calculation for the transport capacity of two 740 m trains carrying 1,600 t in weight. Two different calculations were done to appraise the effect for the IM: first, the price for two 740 m trains each with a 1,600 t weight, and second for one 1,500 m double train with a 3,200 t weight on an example route (about 300 km on a European freight corridor).

Country	2 x 740 m train with 1,600 t weight	Only theoretically calculation – currently not possible 1 x 1,500 m train with 3,200 t weight[2]
Austria	2,272 €	1,745 €
Denmark	945 €	84 €
France*	1,200 €	-
Germany	1,760 €	1,190 €
Hungary	1,650 €	1,195 €
Italy	1,804 €	902 €
Poland	2,390 €	1,902 €
Sweden	710 €	560 €
Switzerland[3]	5,100 €	4,800 €

Table 1: Price calculations for longer trains (examples of pricing systems from 2016) (own chart)

* As described in chapter 1, the approach of longer trains leads to a decrease in track capacity (trains in time) while increasing the transport capacity.

** In France, the pricing depends on the time and type of line. It is not dependent on length, and can vary in a very wide range depending on the time on each network section. Should 1500m long train be allowed, pricing would probably be adapted and cannot be assumed at this stage. Should a figure be considered, one can say that in average, the pricing for a normal train is around € 2 per train per kilometre.

*** The Danish system will probably be changed in 2016. If Denmark had a lot of 1,500 m trains, the system would probably be changed again.

[2] not possible nowadays
[3] energy included

The table shows that with existing track pricing systems longer trains lead to a pricing effect which is positive for RUs and negative for IMs. This has to be considered when aiming at a win-win situation for both RUs and IMs, as this would lead to an increase of long train traffic, with a possible drawback effect on quality if the infrastructure is not fully adapted.

1.5 Definition of train lengths

There is a difference between the physical length of a train and the length the train requires in terms of infrastructure.

The maximum total train length is defined as the maximum length a train (including the locomotives) is allowed to have in an existing railway system.

In infrastructural planning of tracks, extra distances have to be considered to allow signal sighting and imprecise train stops.

In **Germany** a 5 m sighting distance and an additional 5 m for an imprecise train stop are added to the maximum total train length for dimensioning the track length. These additional distances might be larger for trains longer than 740 m.

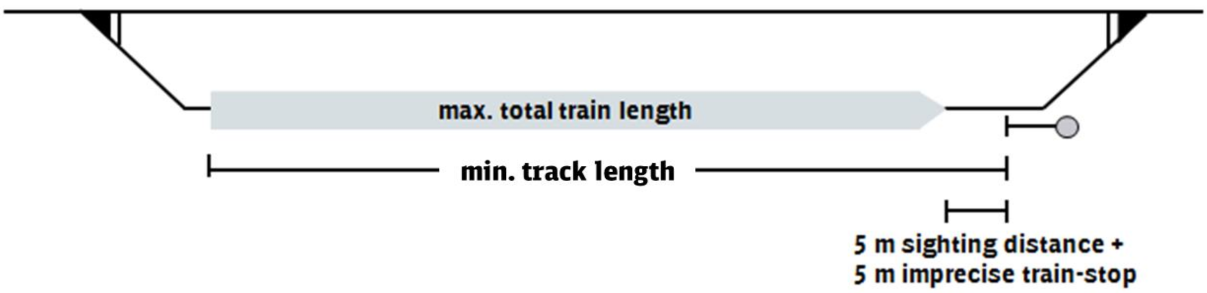

Figure 4: Difference between train length and track length (source: DB Netz AG)

In **Switzerland** as well, an extra distance for imprecise train stops and signal sighting has to be added to the total train length for dimensioning the track length. The sighting distance is defined at 10 m. The length for imprecise train stops is not exactly defined. Usually 10-20 m are added for this. So, a minimum length of 20-30 m has to be added to the total train length to determine the minimum track length.

Another factor for dimensioning the track length is the desired speed of entry. Due to the high capacity utilization on the Swiss railway network, the aim nowadays is to build longer sidings. Trains may run with a higher speed from the main track into the siding so that the main track can be used earlier by the following train.

In **France,** the same technical constraints and similar additional lengths for 750 m trains are needed. It should be outlined that the longer the track, the easier it is to access it at a reasonable speed that will not slow down following trains, but higher the price it is (in average configuration).

In **Austria,** different aspects have to be considered within the definition of the train length:

- the real length of the train composed of wagons and locomotives (with lengthening while in motion);
- the impreciseness of stopping;
- the necessary distance in front of a signal.

For operation purposes, the maximum length of the wagons for pure freight trains is defined at 700 m (DV V3 §24), including lengthening. A total train length of 750 m – composed of wagons and locomotives - is assumed as a maximum.

Taking into account the additional factors of imprecise stopping and the signal view, this leads to a total length of 760 m for designing the line.

In **Denmark,** the train length is considered as the distance between the front of the locomotive and the end of the last wagon while in rest. Lengthening while the train is moving is not included.

In the future, transit route through Denmark (Malmø-Copenhagen-Ringsted-Fehmarn) the sidings will allow 1,000 m trains. There is no specific definition of a necessary track length. For historic reasons, different lengths exist or will be built.

For 1,000 m freight trains, the necessary track length in sidings is considered as the free track length between the limiting infrastructure elements (e. g. fouling points). The design-criteria when using ERTMS level 2 is that track length as an absolute minimum needs to be 1,070 m (this will be realized in Køge Nord).

The planning goal for the Ringsted-Fehmarn railway is to have 1,170 m sidings. Nonetheless, this may be reduced to 1,110 m depending on the space available.

In **Italy,** the maximum total train length is defined as including the locomotives. The track length, defined as the distance between the two ends of the section of a track circuit, must be at the maximum of the whole train length defined above.

In **Estonia,** the standard train length is 800 m (track length 850 m) and on some tracks in specific cases it is possible to drive trains with up to 1,450 m length (track length 1,500 m).

In **Poland,** the maximum length of freight trains is defined as 600-750 m, but the designed total station track length is longer and consists of following sections: maximum train length (600/750 m), track protection between the exit signal and points (50/100 m, depending on allowed speed), isolated track circuit (10 m from the points), additional track length for imprecise train-stop (10/15 m depending on allowed speed).

Thus the maximum station track length required for freight trains is:

- 600 m train – up to 725 m side track
- 750 m train – up to 875 m side track

In **Hungary** the allowed maximum lengths for a train composed of non-passenger wagons are:

- rapid application pneumatic brakes 600m up to 120 km/h speed
- rapid application pneumatic brakes 700m up to 100 km/h speed
- slow application pneumatic brakes 800 m

In **Sweden,** the definition is similar to the one in Italy, that the maximum total *train length* is defined as including the locomotives. The *track length*, defined as the distance between the two ends of the section of a track circuit, must be at maximum the whole train length defined above.

In conclusion slight differences between Member States exist, but most of them follow a similar approach in the calculation of the train length.

1.6 Portability of existing solutions in operating longer trains

A UIC study identified the current rail situation on the use of heavy and/or long trains (heavier than 3,500 t and longer than 740 m) in all the UIC members' regions. In some of these regions different initiatives have been taken with regard to these types of trains in dedicated and mixed traffic conditions[4].

The main objectives of the study were:

- to draft a clear view of the existing businesses for heavy and/or long trains;
- to check the technical and operational challenges;
- to provide recommendations to achieve them.

The following table shows the results of the study regarding train length, train weight and the distance of the long train relation.

[4] Source: UIC Study Heavy and/or Long Trains; Paris, February 2013

Country	max. train length	max. train weight	distance of relation
Australia	2,400 m 2,600 m 3,750 m	29,500 t - -	1,400 km 256 km 1,000 km
Canada	2,100 m 3,700 m 4,300 m	21,000 t 21,000 t 21,000 t	- - -
China	- 2,720 m	20,000 t 21,600 t	653 km 590 km (test)
India	1,200 m 1,500 m 1,500 m	- 15,000 t 15,000 t	950 km 1,839 km 1,515 km
Russia		8,000 – 12,000 t	
South Africa	2,200 m 4,000 m	22,000 t 41,000 t	580 km 860 km
USA	2,000 m 3,000 m 4,000 m 5,600 m	10,000 t - - -	- - - Dallas – Long Beach

Table 2: Results of train length outside of Europe from UIC study *Heavy and/or Long Trains* (own chart)

Most of the solutions from outside Europe are not adaptable to European conditions, because the differences between countries which operate (very) long and heavy trains on dedicated networks are too big. Freight trains in Europe must share the infrastructure with the trains of every RUs and activities, passenger regional trains, long distance trains, as well as with high speed trains running e.g. up to 200 km/h on classical lines.

This high constraint limits considerably the exploitation operation possibilities of longer trains on the different corridors with the existing infrastructure.

In this respect, operating long trains in Europe will probably not benefit from those experiences, but will have to seek for new ideas and other ways of operating those type of trains.

2 Political framework

Summary

Currently, the European Union is focusing on establishing a train length of 740 m throughout the complete TEN-T Core network; only in a few countries governments are actively supporting even longer trains.

2.1 European Union

In the last decade, the European Union has developed and adopted several important policy frameworks for longer and heavier freight trains:

Regulation on technical specifications for interoperability (TSI)

In 2006 the European Union adopted the first technical specification for interoperability relating to the control-command and signalling subsystem of the trans-European conventional rail system. This regulation is regularly (2009, 2012) revised to incorporate technical progress and market trends. The current regulation specifies standards for high-speed rolling stock, freight wagons, locomotives and passenger rolling stock, noise, infrastructure, energy, control-demand and signalling, operation and traffic management, telematics application for freight and passenger services, safety in railway tunnels and accessibility to persons with reduced mobility. For example, the infrastructure section defines the maximum gradients, track parameters, axle load, and line speed for *New lines* and *Upgraded lines*. For the freight train length, the current revised TSI specifies a maximum of 740 m.

Regulation No 913/2010 of the European Parliament and the Council concerning a European rail network for competitive freight

Based on this Regulation, IMs are obliged to establish nine rail freight corridors in Europe. Currently, the IMs involved in these freight corridors are jointly defining and organizing international pre-arranged train paths for freight trains. The aim is to facilitate journey times, frequencies, times of departure and destinations and routings suitable for freight transport services in order to improve the competitiveness of rail freight. According to this Regulation, the Management Board of a corridor has to set up an Advisory Group of Shunting yards (TAG) and an Advisory Group of RUs (RAG) interested in the rail freight corridors. These advisory groups may issue an opinion on any proposal put forward by the Management Board which has direct consequences for the investment and the management of shunting yards or the operation of RUs respectively. The length of freight trains is not specified in this Regulation. **But Rail Freight Corridors must**

follow the criteria of the consistency of the freight corridor with the TEN-T, the ERTMS corridors and/or the corridors defined by RNE.

Regulation No 1315/2013 on Trans-European Network Regulation (TEN-T) and Regulation No 1316/2013 on the Connecting Europe Facility (CEF)

The revised TEN-T Regulation EU No. 1315/2013 is the current transport infrastructure strategy of the European Union, as adapted by the European Institutions at the end of 2013, and entered into force on 1st of January 2014. The text proposes – with a lot of input by CER [5] - 9 multimodal core network corridors corresponding to the nine Rail Freight Corridors as an instrument for implementing the Core Network. The aim is to allow investments and infrastructure works to be synchronized, and to support efficient, innovative and multimodal transport services, including rail services over medium and long distances.

The TEN-T Regulation focuses on projects of European added value, such as the removal of bottlenecks and building missing cross-border links. Other priorities include connecting nodes in order to allow exchanges between transport modes, making better use of the existing infrastructure, and setting clear deadlines and sustainable financial commitments for realizing the network.

More importantly, for rail infrastructure the Regulation defines stringent technical parameters on the TEN-T core network: ERTMS, 22.5 t axle load, electrification, 740 m train length for freight trains, 100 km/h line speed. The EU Regulation 1316/2013 of the Connecting Europe Facility (CEF) is the main financial instrument for realizing the TEN-T network within the 2014–2020 Multi-annual Financial Framework. At the European Summit on 7-87th8th February 2013, heads of state reached an agreement on the EU budget 2014-2020, in which transport is to receive EUR 23.2 bn. This is a significant improvement on the current financing period (EUR 8 bn). The CEF offers very interesting co-financing rates (up to 50 %) for Member States when realizing the core and comprehensive network.

The 2014 CEF Transport Calls for Proposals, which were published on 11th September 2014, were the first calls under the CEF in the area of transport.

An initial budget of€ EUR 11.93 bn was allocated for the 2014 CEF Transport Calls. However, to accelerate the implementation of key projects and boost growth and jobs in Europe the available budget was front loaded and optimised. The budget finally granted to selected projects amounts to EUR 12.77 bn. The 2015 CEF Transport Calls for Proposals, published on 5 November 2015, make **EUR 7.6 bn of funding available** for projects of common interest in the transport sector. These calls are now closed (deadline 16 February 2016).

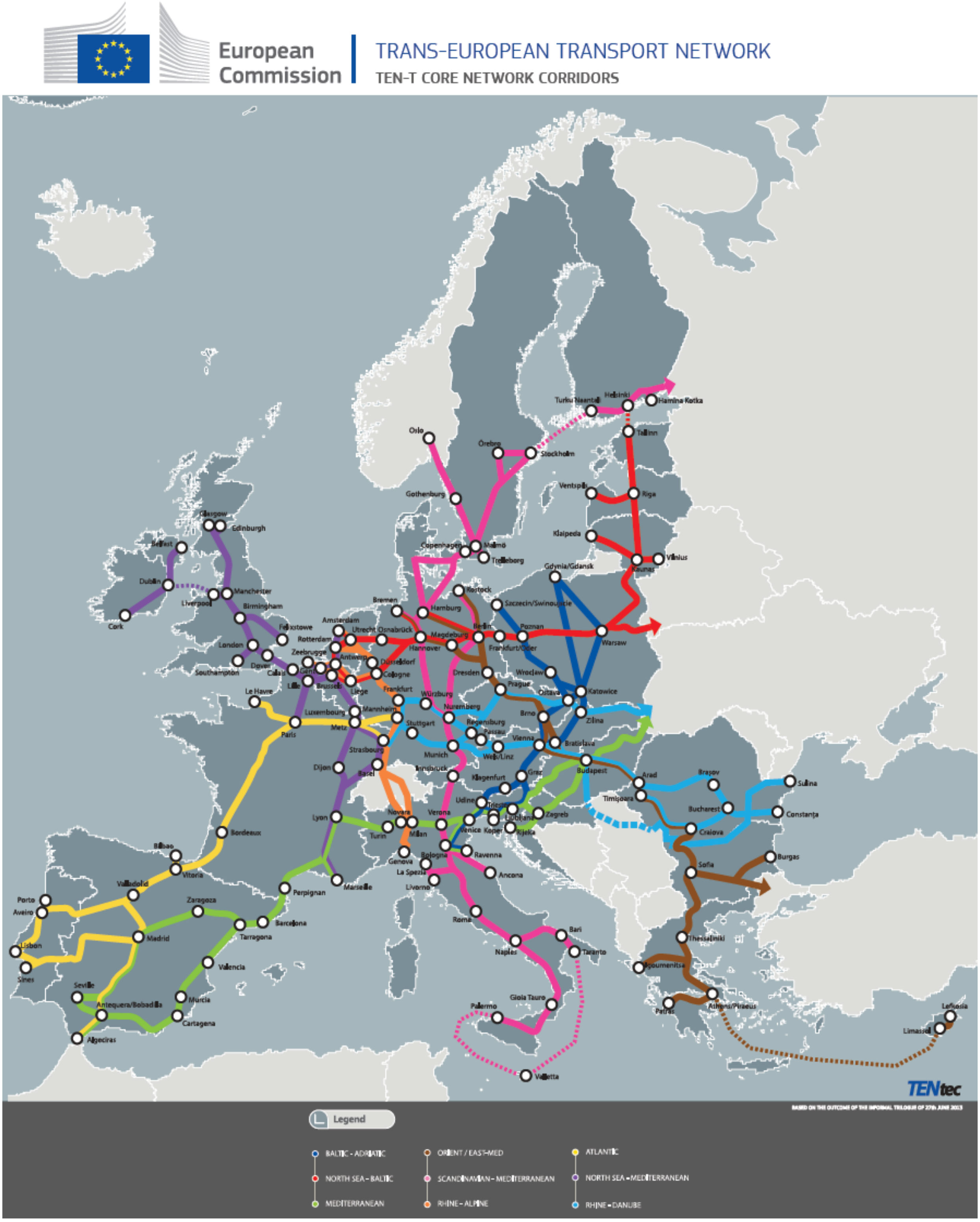

Figure 5: TEN-T core network corridors (based on the Regulation EU No 1315/2013)
(source: European Commission)

2.2 Situation in the various European countries

Austria

Based on the Transport Prognosis 2025+, ÖBB-Infrastruktur AG, in cooperation with BMVIT and BMF, defined the so called *Target Network 2025+* which sets out the lines and installations to construct, upgrade and renew based on market demand and the economic situation of the infrastructure. This is also included in the General Transport Plan of the Federal Ministry for Transport, Innovation and Technology (BMVIT).

This *Target Network 2025+* is in line with the newly revised TEN-T Regulation. Longer train requirements are not included in these strategies for the Austrian network.

Denmark

The 1,000 m train project is not driven by political and planning goals as well as market requirements. Due to the fact that the main freight corridor Copenhagen-Ringsted-Fehmarn will be upgraded in the next years. However, it is expected that new possibilities will be welcomed by the train operating companies.

The goal for rail is to gain a bigger share of the total freight transport market.

As a first step, a great number of investments have been approved to reach the goal:

- track number 2 between Vojens og Vamdrup in the south of Jutland;
- electrification of the rest of the basic rail network in Denmark in the coming decades;
- ERTMS level 2 across the basic rail network in Denmark; and most importantly
- A new / upgraded railway between Copenhagen and Fehmarn, which will offer a high-quality transit route between Sweden and Germany from 2021. This line will allow for 1,000 m freight trains since the dimensions of the sidings will be large enough to accommodate them.

In an agreement between Banedanmark and Trafikverket (Sweden), the two parties intend to establish facilities for 1,000 m trains to be allowed to Malmö, too. However, it is not yet agreed that 1,000 m trains can be received or sent from the north of Germany.

Estonia

Since 2012 the Ministry of Economic Affairs and Communications created a new structure of the Estonian Railway organization. Previously Estonian Railways had direct connection to the Ministry and was two-parted into EVR Cargo and EVR Infra. Nowadays the Ministry itself has direct connection to EVR Cargo and Estonian Railways, which is now the IM. EVR Infra does not exist any longer.

More than a half of the freight volume in Estonia has Russia as its origin country; the other half is built out of Estonia, Latvia, Kazakhstan, Belarus and Lithuania.

The usable length of sidings is 850 m as a standard to run 800 m long trains on the whole network. The standard distances between the route block signals are 1.5 km. Many train stations are already fully developed for longer trains up to 1,450 m. Longer trains can be operated if in the specific case that economic operation is detectable.

France

The French government supports the idea of increasing train length to favour modal shift, and has financed all security system modifications that were needed. However, most of the time longer train are authorized (see section 3.3) without any further state intervention. For some specific projects (Atlantic Rolling Motorway) the Ministry of Transport may decide to upgrade the network to allow longer trains, including side tracks.

Germany

The Federal Ministry of Transport, Building and Urban Development has set up a *Freight Transport and Logistics Action Plan*[5]. This Plan includes conducting field tests with longer trains as one measure to enhance the efficiency of transport. The measure refers to the described activities of DB AG.

Hungary

The train length permitted for the lines are different depending generally on the length of the shortest station on the route.

The train length permission can be extended for a maximum of 800 m named as a too long train running under special traffic management conditions.

A train length of 835 m is an issue of authority permission. The Hungarian Transportation Authority is rather strict on it.

There is no technical hurdle though. 835 m trains might run on the whole MÁV Network under special traffic management conditions.

The engine was not to be counted into the train length till 2008. That meant 800 m + engine (about an 820m train).

Italy

The maximum train length in Italy is limited by the current regulations in force to 750 m. However, at the moment there are no lines where trains of such a length can run (besides a small number of exceptions) due to the limited track length.

[5] http://www.bmvi.de/SharedDocs/EN/Publikationen/freight-transport-logistics-action-plan.pdf?__blob=publicationFile

Poland

Polish (historical) standards for maximum length of freight train: 120 or 150 *axles* (one axle = 5 m) – 600-750 m, additionally, for tracks with a big gradient, room for two locomotives (one locomotive = 25 m) is needed.

Sweden

Standard train length today is 630 m although Trafikverket is striving towards fulfilling the TEN-T regulation to allow 750 m on specified lines. Most shunting yards and marshalling yards are nowadays designed for capacities (length) of 750 up to 1,000 m. There is an ongoing work to allow traffic of trains up to 835 m from Denmark into the first marshalling yard in Sweden (Malmö).

Switzerland

The maximum train length in Switzerland is limited to 750 m (or 200 axles) by the actual train service regulations. At the moment there are no intentions to extend the maximum allowed train length.

The long-term objective is a train length of 750 m on the whole Swiss standard gauge network. In the proposed bill *Financing and Upgrading Switzerland's Rail Infrastructure* (FABI), which deals with the next steps in the development of the Swiss railway network, a harmonized train length of 750 m is included.

3 Experiences, current activities and plans in Europe

Summary

Tests for longer trains have been undertaken in several countries or are still going on. Longer trains have been established on specific routes in Austria, Denmark, France, Germany, Hungary and Sweden. In Estonia, nowadays in special cases trains up to 1,450 m are possible to be operated. Plans for intensive research for train lengths of up to 1,500 m exist in Germany and are foreseen in France. Denmark plans on making investments for 1,000 m long trains, so does Sweden. Hungary's' objective is 1,050 m.

Until now few countries have planned to run trains longer than 740 m or have already had experience with tests or the regular operation of longer trains. The situation and experiences in these countries is described in this chapter, starting with an overview of the train lengths that are allowed in the different countries today.

3.1 Maximum allowed train length

According to the current TSI, new infrastructures must allow train circulation for 740 m (see spread sheet below). Nevertheless, the reality in Europe is different. Due to operational restrictions, the allowed maximum train length is not possible on every part of the network.

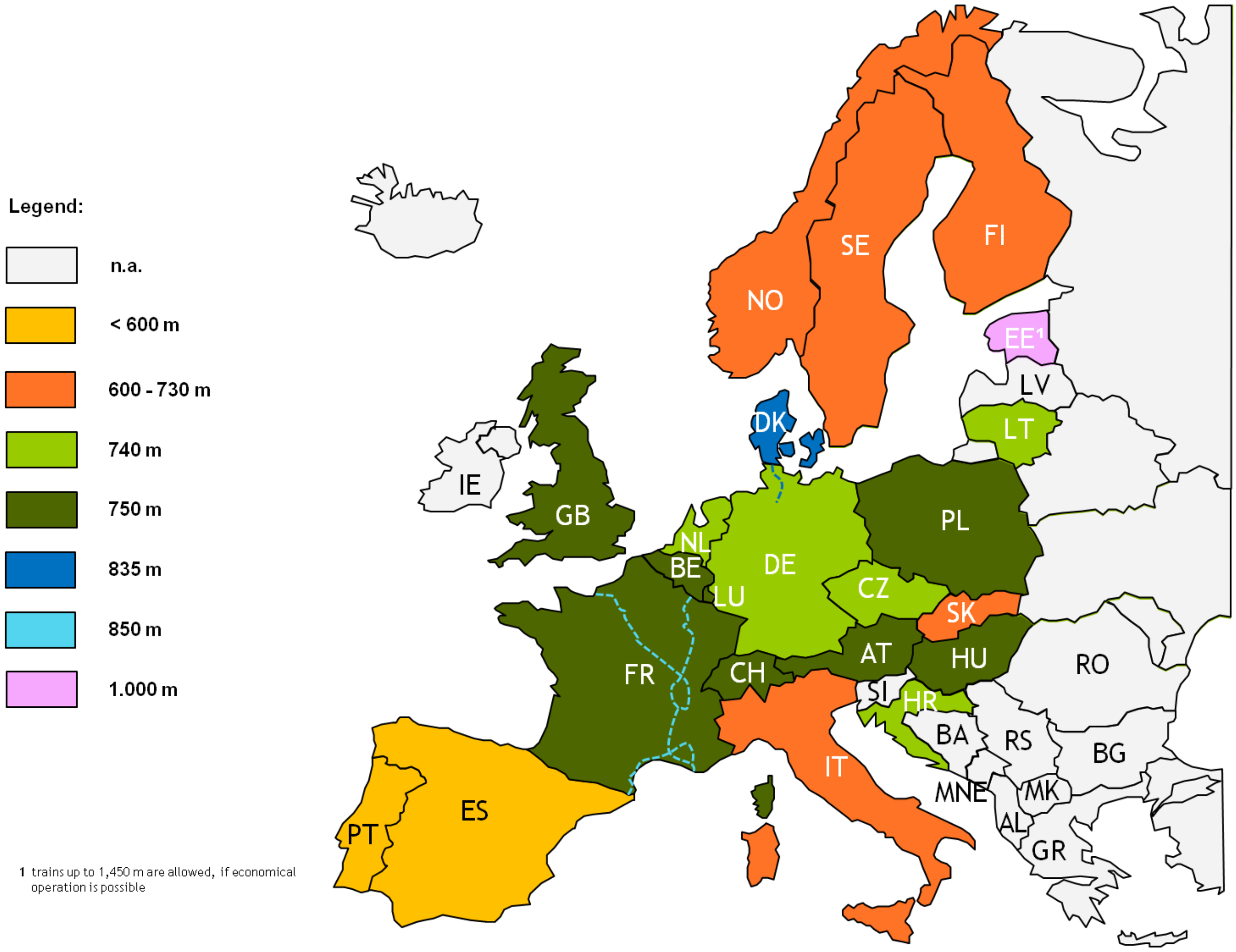

Figure 6: Overview of standard (max.) trains length per country (source: CER)

3.2 Experiences in Austria

RUs can apply for a special permit for longer trains, which is decided by the IM on the basis of the daily situation (case-by-case-management). A permit is granted when:

- the necessary breaking weight percentages are observed (responsibility of the RU);
- tracks are long enough at the beginning and end of the route;
- one or two sidings are usable on the route.

There are no special operational conditions for these trains; they have been operated so far with lengths of up to 800 m.

Longer trains are not included in ÖBB's strategy *Target network 2025+*.

3.3 Current activities and plans in Denmark

Since 1960 it has been possible to operate 835 m trains in Denmark.

In general the experience has been positive, i.e. there have not been very many problems concerning safety, punctuality, traction, loading and reloading, shunting or other activities. Unfortunately the number of 835 m trains has been limited because a major part of the rail freight traffic in Denmark has been transit traffic and the neighbouring countries are not able to operate 835 m trains. Furthermore, national Danish rail freight traffic predominantly consists shorter trains.

When running 835 m trains there are special rules:

- when two trains are passing the Lillebelt bridge at the same time, the total weight is not allowed to exceed 14.4 t/m;
- the train is not allowed to have a total wagon weight of more than 2,500 t;
- because of limitations in Copenhagen Kastrup, it is in one of the directions forbidden to run trains that exceed 779 m between 5 and 24 o'clock. Between 24 and 5 o'clock, the 835 m trains can pass (in Malmø only 750 m long tracks have existed until winter 2014, but now it is possible to handle trains with a length of 835 m);
- trains with a wagon weight of more than 1,200 t are not allowed to run faster than 100 km/h.

Longer trains are very often the cheapest way of extending the freight capacity in the rail network compared to the other possibilities: heavier trains, bigger gauge trains and especially new parallel railway lines.

In the next decade, the rail corridor between Lübeck in Germany and Copenhagen in Denmark will see massive investments in rail infrastructure.

Among the projects are:

- upgrade of the railway from Lübeck to Fehmarn from one to two tracks, upgrade of speed to 160 km/h and electrification (DB Netz);
- new fixed link between Fehmarn and Lolland including two tracks, electrification and line speed of 200 km/h, replacing the existing ferry service (Fehmarn A/S);
- upgrade of the railway from Lolland to Ringsted in Denmark including two tracks, electrification and line speed of 200 km/h (Banedanmark);
- new Storstrøm bridge including two tracks, electrification and line speed of 200 km/h (Danish Road Directorate);
- new line between Ringsted and Copenhagen in Denmark including two tracks, electrification and line speed of 250 km/h (Banedanmark).

The aims of the projects are to increase capacity and quality of railway transport and thereby attract passengers as well as freight to move from road to rail.

In particular, rail freight in the transit corridor from Hamburg (Maschen Rbf) via Denmark to Malmö in Sweden has increased in volume in the recent years. Between 2006 and 2013, rail traffic grew by 75 %. It is expected to grow even more after upgrading the Lübeck-Copenhagen corridor, as the freight trains will then save more than 160 km and their market position compared to lorry traffic will be drastically improved.

However, in order to make use of the possibility to run freight trains of 1,000 m in Denmark and Sweden in the corridor between Fehmarn and Malmö, it is necessary that the upgraded line between Lübeck and Puttgarden is also built for freight trains of 1,000 m. This would imply a change of scope, as the project today is based on freight trains of 835 m.

3.4 Experiences in Estonia

The issue of longer freight trains has already been implemented in Estonia for the standard train length of 800 m and axle loads up to 32 t. Many train stations in Estonia have already been fully developed for longer trains. Train lengths up to 1,450 m are allowed if in the specific case economic operation is detectable, whereas the technical conditions include, among others, the assessment of wagon frames and couplers for pulling and compression forces.

Estonia has about 15 % of its station tracks for a maximum train length of 1,450 m, about 20 % for trains up to 1,000 m and around 50 % for 800 m trains. Only 15 % of its station tracks have a capacity limit of less than 800 m. These stations are concentrated in the west of the country.

The technical conditions in Estonia include mainly the assessment of wagon frames and couplers for pulling and compression forces.

In 2014 only 12-17 percent of freight trains were longer and heavier compared to standard. Estonia found out that agreements with clients and partners are needed in order to achieve suitable logistics and positive effects.

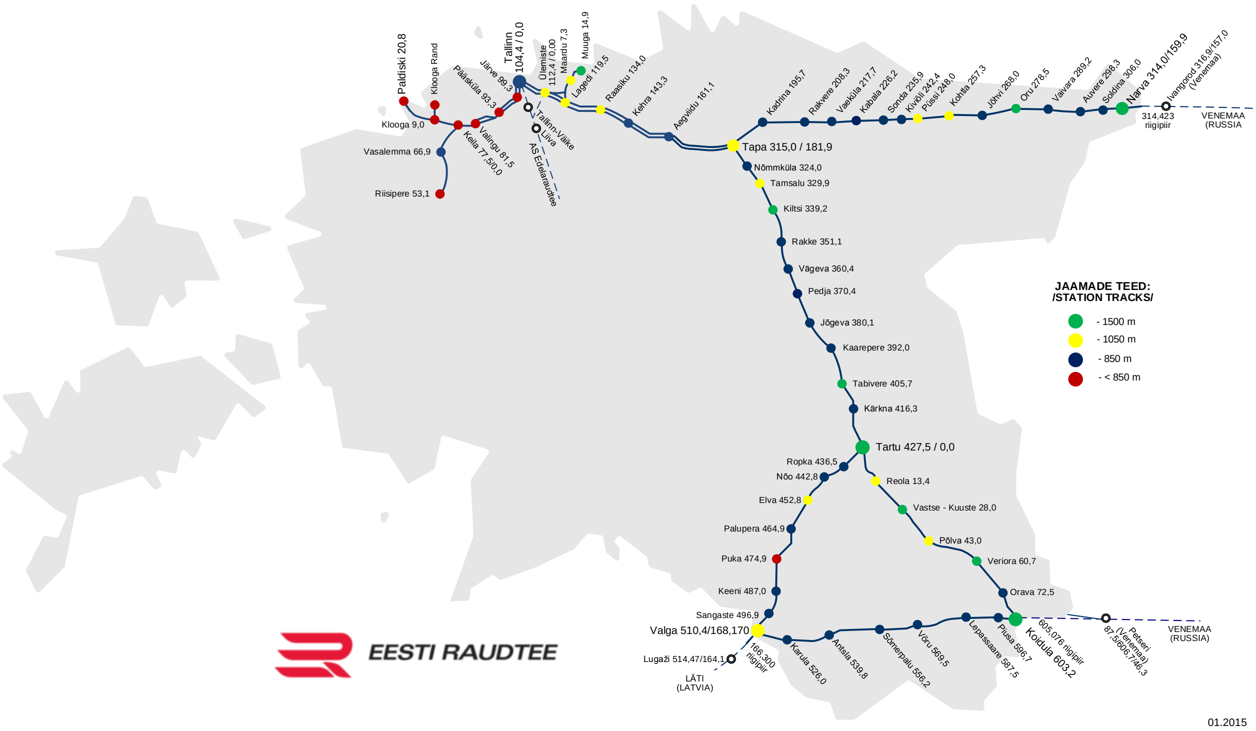

Figure 7: Maximum train length in Estonia (source: Eesti Raudtee)

3.5 Experiences and current activities in France (and Luxembourg)

France allows long trains up to 850 m on a certain number of network sections to favour modal shift from road to rail; the following map illustrates the current state of this development.

As also mentioned above, allowing long trains should imply:

- Adaptation of network security installations
- Building or enlarging existing side tracks
- In case of heavy trains, checking the power stations capabilities, especially when two heavy trains are likely to be powered by the same station
- Adapting shunting yards to ease the access of long trains without disrupting other traffics
- For trains longer than 1000 m, adaptation of emergency breaking systems

However, it is possible to grant paths for long trains even if no network adaptation but security installations has been performed; it is then done on a case per case basis, depending the origin, destination, and time of the ride. If 850 m trains cannot be allowed, for example due to track works or busy hours conditions, the length of the allowed train can be shortened.

There are ongoing tests and studies to allow double trains up to 1,000 m to run between Dunkerque and Metz, along the Belgian border.

The Atlantic project (train length up to 1,000 m; rolling motorway between Lille and Bayonne) has been postponed in 2015; the project is currently being redefined, in all its characteristics, including train length.

For the time being, the itineraries opened to 850 m in France under the above mentioned conditions are showed on following map:

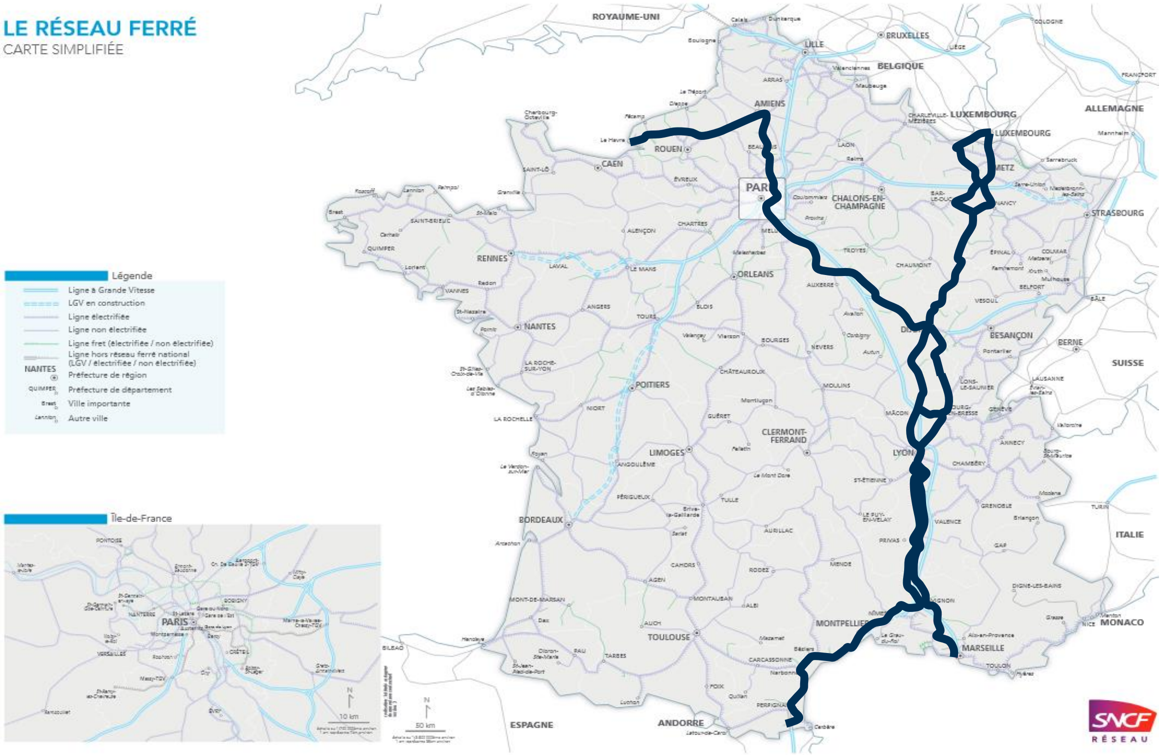

Figure 8: Mapping of 850 m trains (source: SNCF Réseau)

3.6 Experiences and current activities in Germany

The introduction of a maximum train length of 835 m on the route Padborg–Maschen strengthens the international transport link between Germany and Denmark. While in Denmark a train length of up to 835 m is already possible today, the permitted train length in Germany is exceeded on this relation for the first time.

After the successful completion of the feasibility study, carried out from 2005 to 2008, DB Netz AG decided to proceed with regular operation. The preparations for the regular operation with a maximum train length of up to 835 m between Padborg and Maschen were finished in 2012 and included:

- infrastructure adaptions (e.g. increased siding length);

- definition of conditions for train dynamics;
- measures for train lengthening / elasticity;
- expertise for suitability of control and safety system;
- establishing proof of equal safety;
- approval by the Federal Railway Authority;
- definition of special operational requirements;
- integration in network statements;
- consideration in timetable and operational processes.

The introduction of the 835 m trains took place in December 2012. Before that, trains ran over this route with a maximum train length of up to 670 m due to operational constraints along the route.

Since December 2015 it is possible to run 835 m to / from the Port of Hamburg, too. Train path applications are submitted to DB Netz AG via its train path portal (German: Trassenportal).

A movement order (German: Beförderungsanordnung) for the 835 m long trains is issued by DB Netz AG when the train path application is prepared.

Special conditions

For the operation of trains of up to 835 m in length, special conditions regarding safety and operations must be taken into account.

Train operating companies must ensure that all special conditions are observed and implemented during the operation of an 835 m train. In accordance with the current procedure, this must be proven to the Federal Railway Authority on demand.

A planned study within the Shift^{2}Rail program of the European Commission will investigate the feasibility of train lengths of up to 1,500 m. The study will focus on corridors with a high market potential and seek solutions to the technical and operational issues of operating trains with a length of up to 1,500 m. One key element will be the development of a system for distributed traction and braking steering. The study will be based on the results of the previous MARATHON project.

Activities in Germany focus on feasibility, and there are no plans currently to implement longer trains.

3.7 Experiences and current activities in Hungary

In Hungary, a train of 750 m can run without any further special operational measures on the railway network.

The allowed train length for a route is constricted by the shortest track of a station that can be found on the line of the train. Also the weight and the load of the train are defining. The possibility for 800 m train length is given, but certainly the load is crucial, too, because of the rolling stock and the screw coupling.

As for the future, the regulation legislation should be changed, whereby the *French standard* is to be followed and set as a goal. That means the objective is 1,050 m – 3,000/3,500 t – 100 km/h.

Now a 600-700 m long train with a weight of 4,000 t can be forwarded by a single Taurus engine from the Ukrainian border to Budapest. If these trains are to be forwarded towards the West they should be split into 2 trains due to the slopes and the strength of the screw coupling as a consequence. In Hungary the highest slope on the line to Austria is 8 ‰.

Once a new line connecting the Eastern and the Western part of the country from the Ukrainian border heading to the Croatian one (Gyékényes – Koprivnica) that is Rail Freight Corridor VI to the South of Budapest will be built and the maximum slope is 5‰ according to the plans the previously mentioned *French standard* can be reached, whereby in case of a 1,000 gross t train the fees would cost EUR 2,303 (EUR 5.8/ gross t per-unit costs) and of a 3,000 gross t, one makes EUR 4,908 (EUR 12.3). This way a slogan can be: Pay 2 and get 3!

Maximum train length on main lines of MÁV Hungarian Railways:

Destinations	max. train length [m]
Budapest - Hegyeshalom (AUT)	750
Budapest - Hodos (SLO)	600
Budapest - Murakeresztúr (CRO)	600
Budapest - Gyékényes (CRO)	600
Budapest - Sturovo (SVK)	750
Budapest - Miskolc - Hidasnémeti (SVK)	750
Budapest - Záhony (UKR)	750
Budapest - Curtici (ROU)	750
Budapest - Kelebia (SRB)	700

Table 3: Maximum train length in Hungary (source: MÁV Hungarian Railways)

In accordance with Hungarian Brake Instructions E.2., trains exceeding 600 m are allowed to proceed with a maximum speed of 80 km/h. Additionally:

- in case of a train length between 600 m and 700 m, the first five wagons with a maximum length of 100 m shall be adjusted in freight train (in Hungarian, T for *tehervonati*) brake position;
- in case of a train length between 700 m and 800 m, all wagons shall be adjusted in freight train brake position.

There are no restrictions whatsoever for train lengths exceeding 800 m in Brake Instructions E.2. The presumable reason is that the properties of the railway lines would not allow a longer train length.

Trains exceeding the allowed length for the line are taken as too long trains. Too long trains will be approved and permitted by the line manager from requirement to requirement. When approving operation of a too long train special care must be taken, so that running of the too long train will not disturb running of any other trains. Signal men of the route of a too long train will be informed about the running of a long train. Regarding the brake technique the maximum train length is 800 m, but in general the maximum train length is 750 m permitted by the technical regulation in force.

3.8 Experiences in Italy

In Italy, the most important routes for freight trains are from/to the Alpine Cross Border links, where in general high gradients exist. On these routes, with the current operational rules (about traction, breaking, weight, regulatory limits…) longer trains are possible only for limited train categories (empty trains, automotive…) that meet only a small part of market demand. In this framework, tests for a longer train length have not been carried out.

With specific authorizations, heavier trains (more than 1,600 t) can run but after approvals by RFI.

Current Plans for longer trains in Italy

At the moment there are no plans to run longer trains. The intention is to work towards a maximum allowed train length of 750 m on the principle corridor. The development plans of inland and port shunting yard aims for a 750 m train length on the tracks where it is technically possible.

3.9 Experiences in Poland

Currently there are no intentions in Poland to implement longer or heavier trains even in freight corridors as following. Signalling and traffic control systems are designed for trains allowed by Polish standards – longer/heavier trains would require a system refitting (i.e. longer trains require longer circuits and larger distances between signals, braking distances define distances between signals and heavier trains have longer braking distances). There is only one unique case. In May 2015, a company from the PLK

Group ran tests of a heavy train consisting of a ES44ACi diesel locomotive (Kazakhstan-built under GE Transportation license) and 75 wagons. The length of the train was 1,100 m and its weight was over 6,000 t. During the tests the train drove over 22,000 km with different loads (over 70 passes from station Zamość Boratycze LHS to Sławków LHS). The tests were conducted with different speeds (including maximum speed allowed on the line) to check the locomotive and train behaviour, acceleration and braking as well as computer systems.

Why is it unique? This company from the PLK Group (PLK LHS) is both RU and IM and operates a separate railway line (number 65). Line 65 is a 395 km long wide gauge (1,520 mm) line which is not connected to the PKP PLK network (it is connected directly to the Ukrainian wide-gauge railway network). It is a dedicated freight only line with no passenger traffic.

3.10 Current activities and plans in Sweden

Tests have been carried out in the corridor Gävle – Falun during the 1990's with 1,000 m and 1,400 m trains, the latter with double locomotives and in both cases with empty wagons.

In Malmö shunting yard, Trafikverket is preparing a pre-study to assess the possibility of handling 835 m trains from Denmark. Trafikverket supports the ambition to run trains with a length of 1,000 m from Denmark to Malmø. Technically 835 m trains are possible today.

Trafikverket participated in several initiatives for longer trains e.g. a MARATHON project and a national project together with the forest industry named ELVIS. Trafikverket is also participating and leading SP Freight in Capacity4Rail. In Sweden there are preparations to handle 750 m trains in the rail system.

In addition, longer (750 m) heavier (30 t axle load; 8,600 t weight) trains are running up in the very north to carry iron ore from the region of Kiruna to the Port of Narvik in Norway.

3.11 Experiences in Switzerland

For the moment, the maximum train length is limited to 750 m (or 200 axles) by the train service regulations and there are no intentions to run longer trains in the future. Besides passing tracks in Rynächt and Biasca, built together with the Gotthard base tunnel, there are no facilities planned for longer trains at the moment.

But in the past, running 1,500 m freight trains has been discussed as one option to improve freight capacity on the transit routes across the Swiss Alps. It was intended to manage the predicted volume of rail freight traffic (and reach the target of switching goods from road to rail transport) without or with only limited infrastructure adaptations.

SBB was tasked by the Federal Office of Transport to study the conditions for running 1,500 m freight trains from border to border across the Swiss Alps. The trials with test trains in 2004 were successful; technical requirements for the rolling stock as well as infrastructure parameters could be defined.

The timetable study showed a loss of train paths for freight trains in contrast to the general positive capacity effect of longer trains. This is because of the special conditions for the timetable study. A dedicated freight volume should be transported in a given timetable by partial substitution of regular freight train paths by train paths for longer trains. But the longer trains caused a loss of regular freight and passenger train paths (due to the longer track occupation times and special operational requirements) in the pre-defined Swiss timetable and the target for rail freight transport could not be reached.

Due to the loss of freight capacity as well as operational restrictions and the scale of the necessary infrastructure adaptations (more than CHF 1 bn, about 1/3 in direct connection with the longer freight trains), the 1,500 m train concept was not pursued. Another challenge was the safe radio remote connection between the locomotives. The time lag could not be limited with the analysed software solutions and it would be necessary to install stationary repeaters. A cable through the train could be an alternative but would cost about CHF 5,000 per wagon.

3.12 European projects

The MARATHON feasibility study was a European project (participating are e.g. RFF, SNCF Fret and Trafikverket) aiming to realize a train test with 1,500 m *double trains* with the following composition: one standard train (750 m) coupled behind another one, each with its own locomotive. The locomotive in the middle (slave) is radio remote controlled from the locomotive at the head (master), with only one driver in the front.

The market targeted by the MARATHON project is clearly the long or very long distance combined transport from point to point (ports or important industrial shunting yards) in Europe, without marshalling by coupling and decoupling and without adding or removing wagons during the long trip, except for separating the train in two that can each continue to their own end destination.

This system aims to be easy to implement with a simple and reliable organisation, compatible with the infrastructure and traffic management constraints and with the existing wagons and locomotives: the additional equipment studied must be adaptable on every type of European locomotive (radio and braking kits as well as the programming module).

The objective is to perform a diesel and an electric train test and to prepare all the documents in order to write a comprehensive specification for the new system.

End of studies for 1,500 m MARATHON train tests between Lyon and Nimes: Test trains ran in January and April 2014.

Shift²Rail

The EU's new programme for research and innovation (R&I), Horizon 2020 (H2020)[6], will run from 2014 to 2020 with an estimated total budget of EUR 77 billion, of which roughly EUR 6.3 billion will go towards support to the "Smart, green and integrated transport" challenge, one of the 8 Societal Challenges identified under H2020, and reflecting the Union's "Europe 2020" strategy.

The aim of the "Smart, green and integrated transport" challenge is to boost the competitiveness of the European transport industries and achieve a European transport system that is resource efficient, climate- and environmentally-friendly, safe and seamless for the benefit of all citizens, the economy and society.

Within this challenge, a budget of EUR 450 million has been earmarked for research and innovation activities in the rail sector. This represents close to three times more than the EUR 155 million in Union funding that was available under the previous research framework programme (FP7), which ran from 2007 to 2013.

The rail sector can and must further enhance its performance through innovation. Innovation should be envisaged as a tool with a dual purpose of helping to address short/medium term problems in the railway sector while also initiating a paradigm shift for a more ambitious future for the rail sector.

In line with this, the Shift²Rail Joint Undertaking was established by Council Regulation (EU) No 642/2014 of 16 June 2014 as a public-private partnership in the rail sector with a view of managing and coordinating all rail-focused research and innovation activities funded under Horizon 2020.

The main task of the Shift²Rail Joint Undertaking is to develop, integrate, demonstrate and validate innovative railway technologies and solutions with the objective to improve the competitiveness and attractiveness of the European Railway Sector.

The work conducted within the Shift²Rail framework will be structured around five asset-specific Innovation Programmes (IPs), covering all the different structural (technical) and functional (process) sub-systems of the rail system, and five crosscutting themes (CCA), that are of relevance to each of the projects and takes into account the interactions between Innovation Programmes and the different subsystems:

[6] Regulation of the European Parliament and of the Council establishing Horizon 2020-The Framework Programme for Research and Innovation (2014-2020), SEC(2011) 1427 and SEC(2011) 1428-Volume 1

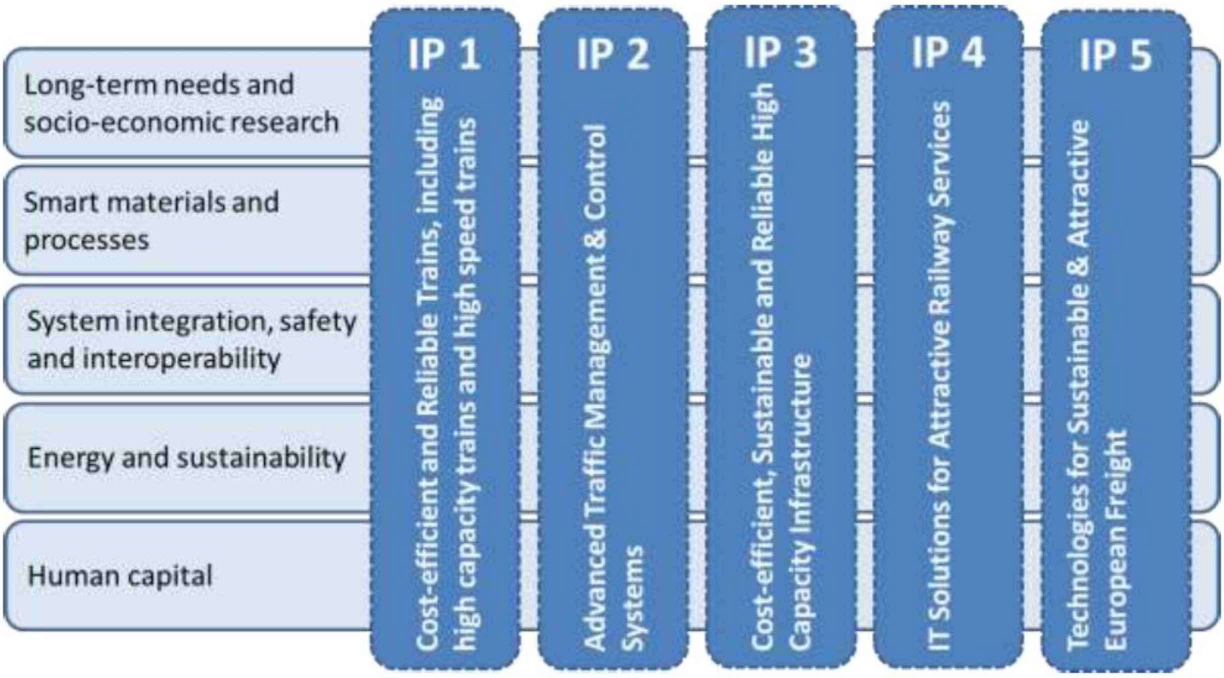

Figure 9: Structure of the Shift²Rail Programme (source: Shift²Rail)

Shift²Rail will address the above mentioned IPs and CCA with 3 funded types of activities:

- Demonstration activities (TRL 4 to 7)
- Research and technological development activities (TRL 1 to 3)
- Other supporting activities

The actual rail market share in land freight transport for the EU has been maintained in a poor fraction, dropping between 2000 and 2011 from 18.5% to 17.4%, despite an increasing penetration of new entrants in this market. The major objectives of the EU White Paper like the Shift of 30 % of road freight over 300 km to rail by 2030 or doubling the transport by rail freight compared to 2005 becomes hard to achieve. Therefore one issue of IP 5 is to develop new propulsion concepts for rail freight traffic because the current situation of EU rail freight traffic is not satisfactory. [9]

Within this context, the feasibility of freight trains up to 1,500 m in length will be proved. The focus in first step will be on developing and testing a remote control for distributed power, thus, allowing to run coupled double trains with train lengths up to 1,500 m and thereby consequently improve the cost efficiency of rail transport.

The final aim of the Long Trains (LT) work stream is to fully develop a technical solution for the regular operation of 1,500 m long freight trains. Starting from the MARATHON results, the project aims to confirm the actual market potential for the distributed power technology, to assess and reinforce the safety concepts behind this technology, to extend the applicability analysis to a wide range of train configurations and to ensure the real life applicability of the technology without there being any obstacles. LT will implement all the functions needed to safely set up and run the train according to proven safety standards. LT will also provide the real-time facilities interacting with the driver and with the infrastructure ensuring a safe and efficient operation. Improved train availability will be provided, even in the temporary absence of radio signals, preventing undue track occupation that could affect normal passenger traffic. Laboratory tests will prove the braking performances over the 1,500 m. The proposed and conceptually assessed solution will be tested and validated in the relevant environment. The deliverables produced will be propaedeutic for the application of a process review resulting in a homologation.

Furthermore, the project is designed to identify the actual market potential of long freight trains, the necessary measures for infrastructure, operations and rolling stock and the economic effects for Railway Undertakings (RU) and Infrastructure Managers (IM) in a business case.

CEO Taskforce

The European Rail Freight CEOs decided at the last CER/UIC High Level Freight Meeting on 22 May 2015 to create a Taskforce for the benefit of the rail freight. A range of issues should be tackled urgently in order to maintain the profitability of freight operators. The various issues have been clustered in four categories developing quite a lot of important and urgent issues: innovation, interoperability, rail operation and corridors.

17 projects were initiated including standardised parameters including longer and heavier trains. The goal is to make rail freight operations more seamless, cost effective and competitive, and enable more new entrants to enter the international markets in which different restrictions currently present an obstacle. Harmonized technical parameters such as train length and loading gauge reduce complexity of planning and optimize the use of capacity. Therefore and in addition for increasing freight productivity, the CEO Taskforce is going up to ask for 1,500 m long freight trains. This task should be undertaken corridor by corridor to take into account the different market circumstances.

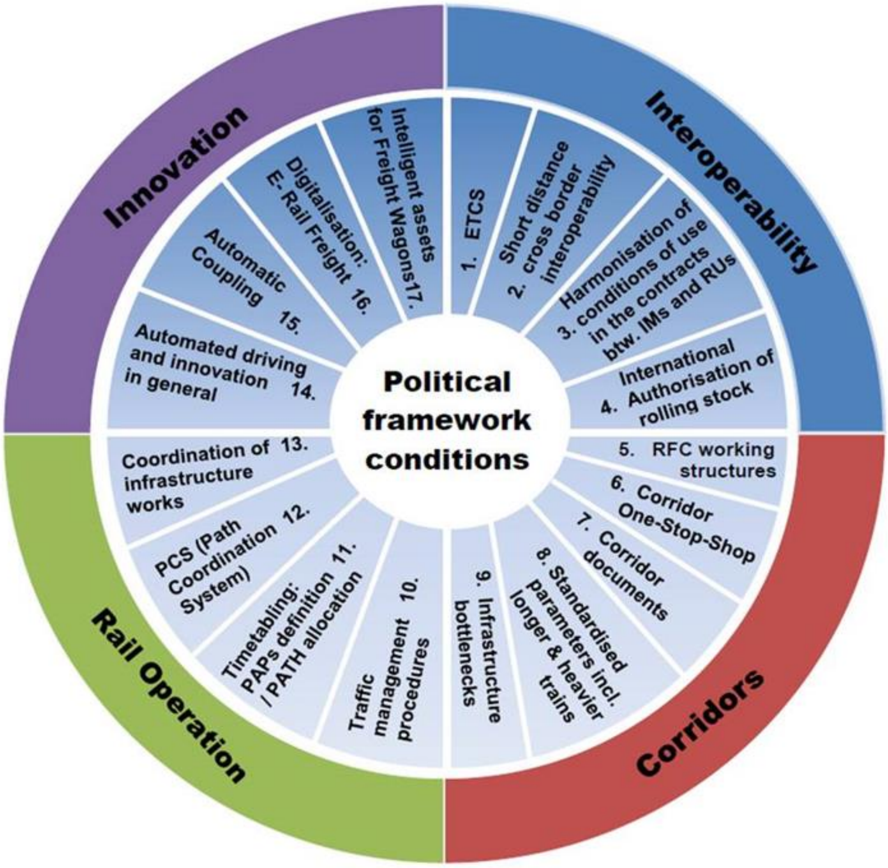

Figure 10: Clusters and projects, CEO Taskforce (European Rail Freight CEOs)
(source: CER/UIC)

4 Operational and technical issues

Summary

Operation of longer trains can only be established if solutions are found for all operational and technical issues ensuring a high quality of operation as well as the expected capacity effect. Different approaches exist concerning the marshalling of longer trains, their operation and the management of train failure or infrastructure failure.

The existing solutions for train lengths of 835 m and 850 m long trains vary. Even longer trains require solutions especially for train dynamics and the control and safety systems to ensure safe operations. Depending on the pursued train length, this will include not only solutions and adaptions on the infrastructure side, but also to the equipment for existing rolling stock. Extensive research in many issues is still necessary.

One condition for the use of longer trains is to ensure a high quality of service without an impact on the operation of current trains. This leads to operational issues that have to be considered when planning longer trains.

Conditions for the operation of longer trains have to address technical solutions for a number of technical issues to ensure safe operations.

This chapter - put together by the different countries - describes the issues and measures undertaken in the countries with experience from tests or regular operation of longer trains and explains the technical problems they encountered. Solutions for the issues vary.

With such an assumption, to run long trains up to 1,500 m, there are two different possibilities to exploit:

- Trains up to around 1,000 m with one locomotive or double traction (one driver leading a *double power unit* composed of two locomotives [mainly of identical series] connected together by cables)
- A remote control of two locomotives (led by only one driver): one master loco leading, one or more slave locomotives in the middle (or at the rear). Both locos must be connected in order to let the master send the commands to the slave, either by cables (the wagons between must then be equipped) or by radio transmission, which is already used on other continents (see UIC study [7]) and studied within the MARATHON project.

In addition, the infrastructure installations have to be adapted (fixed installations as well for existing longer trains) in order to allow the running of such trains, but also their management in traffic, as the lines involved can potentially admit trains with speeds between 100 and 220 km/h. Tracks that are long enough must be built (works for new tracks or adaptation of existing ones) in passing loops, depending on the traffic density, and shunting yards may have to be upgraded to allow such trains to be received without impacting other traffics.

4.1 Composing and decomposing longer trains

Composing long trains (around 1,000 – 1,500 m) requires at least two locomotives because of train dynamics (see chapter *Train dynamics*). This necessitates having enough adapted long tracks to compose the train and also to park it on sidings to let it be overtaken by other trains when required by the traffic management.

Inconveniently, the need for long tracks is probably very high, if we take into account the traffic density and its management, with high differences of speed on the main corridors. Also inconvenient for the RUs is to have long-tracked shunting yards/points in which to marshal such train compositions (including all tasks like brake tests).

France

Whatever its type (Classical or Marathon), a long train remains difficult to park when needed. In this respect, Marathon trains does not help a lot as there is only one driver : separating the train in two on too short side tracks will not be possible as part of the train will be on main lines, on which, if such need occurs, traffic is likely to be dense. Operations must avoid as much as possible operations on main tracks for security reasons and capacity management. Also, from a commercial point of view, it is difficult to imagine half of a Marathon train could be left behind unexpectedly.

When failure occurs, it is felt that train rescue could be easier with Marathon trains, but this has to be carefully demonstrated; tests and theoretical cases will be developed to precisely evaluate this point, as this assessment may vary a lot when taking into account the precise operational circumstances.

The real advantage of Marathon trains compared to classical long trains it behaves more or less like half long trains, whereas classical long trains are less reactive when wagons are added to the train. In this respect, classical trains could less easily fit into traffic grid.

Marathon trains could also be used to solve the shunting yard access or dense area crossing issue, if the separation of the train in two parts could be done before reaching those critical areas.

In other words, Marathon trains are likely to offer some new possibilities which need to be carefully studied from a system point of view, to better balance the constraints between IM and RUs.

The inconvenience of Marathon trains (compared to classical long trains) is that the economic logic behind should lead to very long or very heavy trains, leading to building longer side tracks, which will be more difficult to implement, and more expensive to realise.

The question of emergency breaking systems for trains longer than 1,000 m has to be addressed.

For classical trains, a balance has to be found between RU benefit (which would lead to as long as possible trains), and IM constraints (less side tracks available, more difficulty to fit the train in, in dense traffic conditions). It seems that from this point of view, 850m is a kind of trade-off, especially when only one locomotive is needed.

Germany

The first estimations have already been made for a coupling and sharing concept to make two regular trains into *double trains*. The idea is to build up specially equipped stations for coupling and sharing trains. In a first rough estimation the necessary infrastructure for these stations was appraised. It showed that one track is not enough when more than two long *double trains* have to be handled.

The estimation further showed that composing or decomposing one *double train* would take about 15 to 30 minutes. The even more critical aspect is the waiting time of the trains. When the first train part is waiting for its partner, the track is blocked for every other train movement. Additional waiting time because of delays would be a big issue in rail freight transport and can probably only be handled with additional infrastructure.

Estonia

A scheme of train forming is very important for safe operations: Light wagons have to be at the end of train**.**

4.2 Sidings

Depending on the existing track length of sidings, works could be required in order to allow crossing and/or overtaking Depending on the site constraints, lengthening tracks can be difficult, and lead to minimum size adapted for a given train format; it should also be underlined that the side track must be well positioned to be useful (for example, near a congestion point, on heterogeneous traffic sections, etc.), or regularly positioned along the path.

France

In France, no sidings have been built; when suitable and possible (remote-controlled), existing sidings can be used; if not, the train will not be allowed to ride at 850 m length, but at 750 m.

Germany

In Germany the distance between tracks for overtaking is laid down in the standards of DB Netz AG. The distances between tracks for overtaking are suggested according to the different line standards (e. g. mixed line, passenger line, freight line). It has to be ensured that the necessary siding tracks for overtaking are long enough for longer trains.

Because of the different conditions on different lines, it has to be shown in timetable and operational studies how many siding tracks are needed for operating longer trains on a certain line for a certain train operating program.

To determine the necessity of sidings is always an iterative process between those responsible and the results of timetable studies and simulations.

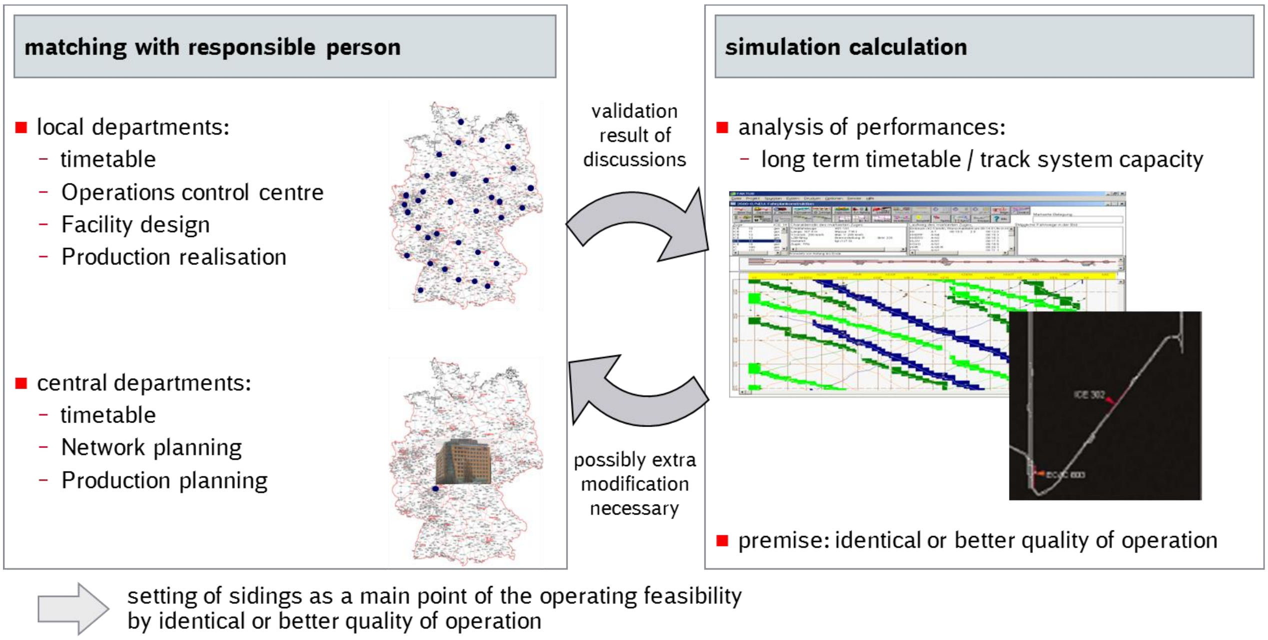

Figure 11: Procedure of identifying necessary sidings at DB Netz (source: DB Netz AG)

Poland

As it was shown in chapter 1.4 in Poland maximum station track length required for freight trains is:

- for 600 m train – up to 725 m side track
- for 750 m train – up to 875 m side track

They are not long enough for trains longer than 750 m. PLK does not avoid the construction of new ones for the aim of implementing longer trains to the rail network managing.

Estonia

Analyses of train time-tables and the determination of suitable passing tracks have to be done.

In the organization of the traffic management, the alternative routes can also be equipped for more fluidity. If not, procedures must be planned in order to avoid misdirection. The timetable is also adapted on the alternative routes in order to get an equivalent path.

4.3 Management of train / infrastructure failures

In case of train or infrastructure failures, measures have to be defined to deal with longer trains. This can be measures in the infrastructure (e.g. alternative routes or additional sidings) and/or operational measures.

France

Depending on the density of the traffic on the lines involved, different measures are under investigation.

In case of high density, additional siding tracks will probably have to be built to give the needed fluidity to the traffic regulation.

In other cases, special scenarios have to be worked out, depending on the train failures, composition, origin and type of train rescue and rescue team, in order to minimize the traffic interruption on the line.

Germany

In cases of infrastructure failure, different solutions for longer trains need to be defined, including alternative routing and train decomposition. Two different scenarios have to be considered:

- major failures without sufficient advance notice (e.g. accidents, derailments);
- major failures with sufficient advance notice (e. g. construction works).

Situations lacking preliminary notice can only be handled on an ad hoc basis. If one line is closed, all trains have to stop and wait until the problem is resolved regardless of the train length. All trains with proper alternative routes can, depending on their parameters (length, weight, gauge…), pass the disturbance on an alternative route. If there are no proper alternative routes, trains have to be fitted to the conditions of the alternative routes available or must be held in starting shunting yard. In any case this situation causes massive overload on lines, in the stations and shunting yards.

In case of construction works with sufficient advance notice, it is possible to reroute all trains depending on the capacity of the alternative routes. Trains with special requirements (e.g. long trains) can be planned on proper routes or with a reduced length and will not cause capacity problems.

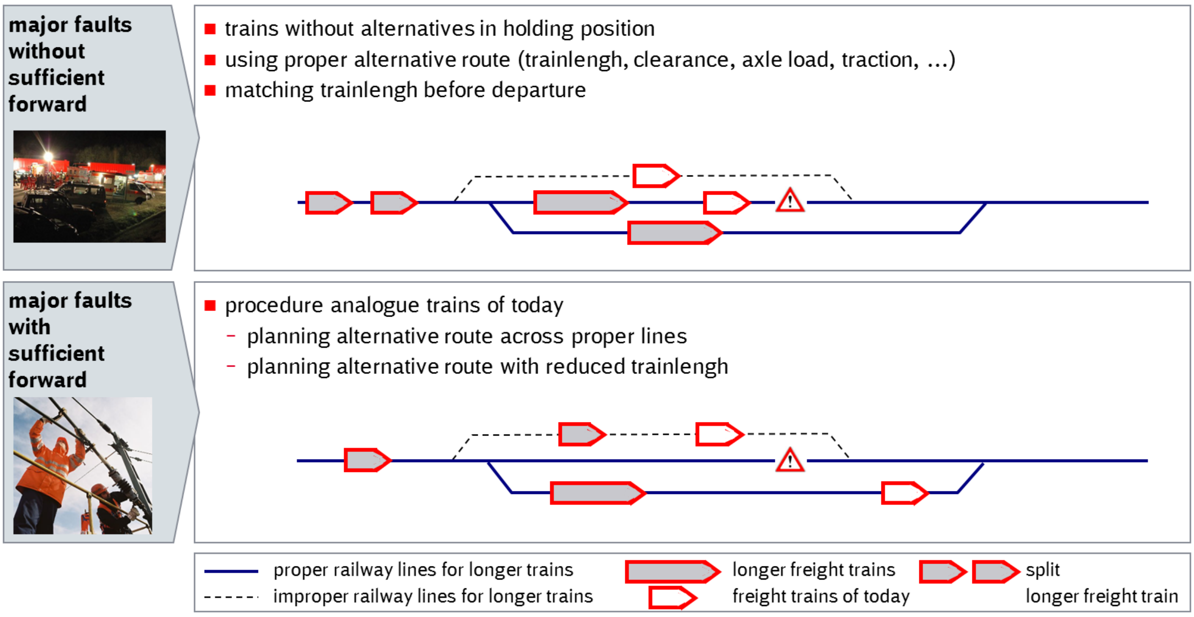

Figure 12: Reaction to major failures (source: DB Netz AG)

4.4 Misdirection

For the operation of longer trains on a certain relation, the infrastructure on the relation has to be adapted. There is a general risk of misdirection, which in case of longer trains leads to the situation that the train will then be on a possibly not suitable infrastructure.

France

Before the departure of each longer train, a written notice has to be sent by the RU to the IM, which will then inform the traffic management divisions of the trip that this specific train will be longer than 750 m. This aims to avoid any misdirection due to the unusual train length.

Germany

If a misdirection of an 835 m train between Padborg and Maschen happens on a line or a section of the line that is not adapted, it could lead to safety problems.

Because of this, there are very strict regulations for 835 m trains in case of misdirection:

- the 835 m train has to stop immediately and the driver has to ask for instructions to the traffic controller;

- if the misdirected 835 m train had already passed a block signal and another train is following on that section of line, the following train has to be stopped immediately too;
- if the misdirected 835 m train had already passed a level crossing, all trains at the section of line at the level crossing have to be stopped;
- if the special conditions for 835 m trains cannot be observed, the 835 m train is not allowed to run. If a misdirection happens, one of the following measures has to be realized:
- **pushing back** the 835 m train and continuing the run on the permitted line;
- **shortening** the 835 m train to the allowed length and continuing the run;
- changing from train run to shunting movement, **pulling back** the 835 m train and continuing the run on the permitted line.

4.5 Train dynamics

In addition to the adaptation of the infrastructure equipment, the studies for longer trains with a length above 740 m must take the behaviour of the train itself into account.

When the main brake pipe is opened only at the front to brake a train down, there is a time offset between the start of braking of the first and the last wagon. While the first wagons already have full braking power, the last wagons are still pushing because the braking signal has not reached the end of the train. The last part of the train is running up onto the first already braking part and it comes to high **compressive forces** at the couplings between the wagons. If the longitudinal compressive forces become too strong, they may in combination with other factors (such as tight curves) lead to a derailment of the train. How long the time offset of the cylinder's response will be, particularly depends on the train length and the braking position.

The reverse happens when the train starts to move. While the first wagons already run the last wagons still have braking power. This causes longitudinal **tensile forces** which could lead to a breaking of coupling. The distribution of locomotives in the train could be a solution but a limitation of the time lag between activation of the brakes on the master loco and the reaction on the slaves has to be ensured. The longer the trains are, the heavier they will be. Tensile forces within the train can get higher than the couplings can tolerate.

Compressive and tensile forces have to be evaluated in order to avoid derailment (compressive forces) and coupling breaking (tensile forces). Some NSAs require the operating RU to bring the proof of the equivalent safety level that means to demonstrate that longer trains are at least as safe as a reference train.

France

The longitudinal compressive forces (LCF) for the 850 m-trains are checked in service and emergency braking (at 30 km/h speed for both cases). The measured LCF are compared to the admissible LCF of the wagons of the train. If the first ones are lower, the new composition is accepted. If they are higher, a statistic comparison is done between the global risk level of the new composition (850 m) and the reference train (750 m) in order to guarantee the equivalent required safety by the national safety authority. To be accepted by the French safety authority (EPSF), the comparison shall consider similar trains (P braking mode with P mode, or G mode with G mode), as well service braking results compared with service braking results.

It has been shown that the compressive forces for 850 m-trains are higher than for 750 m trains, especially in case of emergency braking in short radius curves: the experts took such a case into account to check the equivalent safety and thus cover the derailment risk.

This conclusion obliged to build trains (combined transport) only with high performance (HP) wagons (admissible LCF above 400 kN), that are able to tolerate a high level of LCF. In mixed compositions (wagons with admissible LCF above 400 kN and other wagons LCF equivalent to 400 kN) the lower ones must be placed at the rear of the train. These constraints disturb the operators on the shunting yards and other solutions have to be found out, like other calculations methods which allow simplified safe compositions.

Germany

The German method of demonstration to the German national railway authority (EBA) is a bit different from the French one described above, that can lead to different conclusions, which could allow other interesting compositions for the RUs, despite the wagon categories are the same.

For the 835 m trains it could be shown with a statistic evaluation, that there are no special measures needed. The average level of compressing forces is not higher than the average level within 740 m trains. This effect occurred, because longer trains are mostly heavier and there are a larger number of longer trains running in braking mode G. With braking mode G the braking power increases more slowly and the compressing forces are not so high.

Switzerland

The longitudinal forces were one of the difficulties encountered in connection with the test trains in 2003/2004. A limitation of the time lag between activation and reaction of brakes would limit the longitudinal forces during braking and acceleration. The use of electric brakes (no time lag) or distributed traction power (reduced time lag) had been identified as possible solutions. The challenge within distributed traction power was the remote control of the locomotives at different positions in the train. Radio remote control systems caused a time lag which led to increasing longitudinal forces. The time lag could not be limited with the analysed software solutions and it would have been necessary to install stationary repeaters. A cable connection between the locomotives would have been a solution but requires special equipped wagons between the locomotives.

Estonia

The assessment of wagon frames and couplers for pulling and compression forces has to be done.

Locomotives' (pulling) power and speed characteristics need to be examined (EVR: 2TE116 - 2250 kW and GE C36-7i - 2680 kW or 2xC36-7i – 5360 kW) as well as the line profile and curvature (min. speed required, safety, etc.; EVR max. gradients <0,01 min. R~300m on main lines).

4.6 Compliance with given braking and deceleration distance

The maximum allowed braking distance is defined by the relevant infrastructure elements (pre signalling distance). All kinds of trains have to bring enough braking power to observe these fixed braking distances. Longer braking distances may cause infrastructure adaptations because today's infrastructure is normally designed for a certain maximum train length (safety and control systems, distances between signals, etc.).

The greater the train length is, the more the braking distance of trains increases due to a slowdown in the build-up of the total braking force. This leads to a reduction in the average delay and thus to larger braking distances at the same initial speeds. As a result, the braking distance also depends on the train length.

The braking distances must be checked according to the train length, weight and the braking mode (calculated braking weight of the longer train).

France

The new composition must have a braking weight which guarantees the same braking performance as the reference train, which itself must be compliant with the shorter block system length.

Each RU owning locomotives and each wagon's owner is responsible for the brake modifications and investments on longer trains, as well as the brake control from the leading locomotive, and the locomotive speed control. The owner of the rolling stock is responsible for the update of its Safety Certificate, and its validation by the French National Safety Agency (EPSF).

The 850 m-trains are running:

- either in G braking mode with 100 km/h speed (MA100 named), in which case the allowed train load is 2,400 t with 69% required braking weight (Bettembourg/Le Boulou) instead of 54% on 750 m/1,800 t trains;
- or in LL braking mode with 120 km/h speed (ME120 named), in which case the allowed train load is 1,800 t with 91% of required braking weight instead of 86% on 750 m/1,800 t trains (Paris-Marseille).

Germany

To consider the slowdown of the build-up of the braking power of longer trains, the 835 m trains between Padborg and Maschen have a braking weight reduction of up to 5 % in braking mode G, and up to 20 % in braking mode P.

Estonia

The assessment of trains' braking systems is indispensable regarding capacity and speed of *brake wave* (for 2xC36 locomotives max. 520 axles are permissible because of compressor characteristics).

Poland

The absolute braking distances are defined by PKP PLK internal regulations according to the speed on the line regardless of the used braking system. On the railway lines under PKP PLK's management it is:

- 1,300 m on lines with the speed 141 km/h – 160 km/h
- 1,000 m on lines with the speed 101 km/h – 140 km/h
- 700 m on lines with the speed 61 km/h – 100 km/h
- 500 m on lines with the speed 41 km/h – 60 km/h
- 250 m on lines with the speed below than 40 km/h

On lines up to 160 km/h allowed braking distance is calculated by ETCS devices on board. To keep these distances RUs must calculate themselves the percentage of the required braking weight of the train depending on its weight.

4.7 Lengthening of trains / Elasticity

The composition of the train (number of wagons which equals to the number of couplings, and the type of coupling, such as bars or classical UIC-coupling) has a noticeable influence on the elasticity. Elasticity is described as follows: just after the stop, the train gets shorter due to the compression of the couplings. Just after releasing the brake, the train resumes its original length, stretching backwards, which means that it is slowly going back, although the locomotive is still standing at the same place: This is meant by lengthening or *elasticity*.

It is possible that after the release of the brakes a train stretches itself beyond the boundary marks which it had cleared already, so that the following train or shunting movements could be endangered.

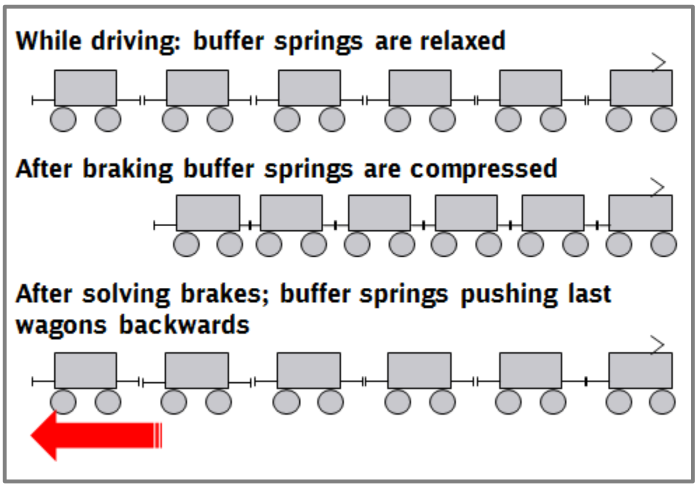

Figure 13: Lengthening or Elasticity (source: DB Netz AG)

France

Some safety equipment of the infrastructure placed on the track behind the rear of the longer train has to be adapted in order to keep its safety role (e.g. safety distance between trains through the *block system*).

Germany

For the 835 m trains between Padborg and Maschen, an operational solution was chosen. The results of a study show that the number of couplings has the strongest influence on train lengthening. Today, there are up to 84 wagons possible in a 740 m train (using the shortest wagons in Germany). In order to limit the lengthening to today's value, 835 m trains are also restricted to a maximum of 84 wagons.

Poland

In Poland the number of couplings has the strongest influence on train lengthening. So we limit the number of wagons in the composition of the train. There are maximum 52 wagons possible in a 750 m train operating on the railway network managed by PKP PLK S.A. One line managed by PLK Group (PLK LHS) – line 65 – operate trains consisting with 75 wagons.

4.8 Suitability of control and safety system

Beside ETCS there are different control and safety systems within the European rail network. It must be observed whether these systems can handle longer trains, since they are constructed for a certain train length.

France

The current French linear safety control system is KVB. The possible length is technically limited to 790 m on board system but after some studies and taking into account margins in braking distances and acceleration, EPSF has decided to allow up to 1,000 m long trains in France on some sections of the network.

In the future, for trains that would be longer than 1,000 m, there is **more technical uncertainty about linear safety control system with huge economic and technical impacts for both RUs and IMs:**

- compliance with braking distances;
- length of trains in areas with reduced speed limit (excessive speeds of the train's last wagon in the area);
- management of the transition between KVB and ERTMS during the deployment of ETCS1.

Germany

Two different systems are used within the network of DB Netz AG: the punctate control and safety system (PZB) for lines up to 160 km/h, and the linear control and safety system (LZB) for all lines faster than 160 km/h.

When running under the **linear control and safety system (LZB)** the train data has to be entered respectively and controlled before every train run (e.g. after changing the driver without switching the train settings). The maximum of the possible entered train length is limited to 790 m due to the current system functionalities. This means that train lengths over 790 m cannot be handled by LZB.

If the actual train length is larger than the entered train length in LZB, there could be excessive speeds of the train's last wagons due to too early acceleration while driving through speed restrictions or areas of crossovers.

The **punctate control and safety system (PZB)** has no technical restrictions with respect to train length. But the possible train length is due to restrictions of LZB limited also to 790 m for the combined vehicle equipment. If misdirection takes place on a track equipped with LZB – contrary to the requirements of the system definition – the device could automatically change into LZB mode, which could lead to the risks described in the paragraph above.

835 m trains are not allowed to run on LZB controlled lines. To avoid safety problems with the LZB, the LZB device on the traction unit must be switched off before the train starts.

For the route Maschen–Padborg, no problems arise from this issue. The whole route is equipped with PZB. The measure to switch off the LZB device before running the train is taken only to provide for the risks arising from a possible misdirection on a line equipped with LZB (directions Berlin or Hannover).

4.9 ETCS

The implementation of a new train control system can be a chance to overcome the restrictions of today's systems. The technical maximum train length for ETCS is set to 4,095 m.

For the actual software version for infrastructure and the locomotive devices (baseline 2.3.2d), no braking curves for longer trains exist. Braking curves for freight trains up to 1,500 m are already available only for the proposed next software version (baseline 3). This could cause additional costs for updating the software of infrastructure and locomotive devices from baseline 2.3.2d to baseline 3.

4.10 Occupation of several block sections

Making trains longer could cause, depending on the track conditions, a single train occupying more block sections simultaneously than is the practice today. If this is not scheduled within the signal box planning, there could be incidents. Therefore, it must be ensured that the longer trains do not cause unsafe conditions.

France

For 850 m trains, in the sections of the network where those trains are allowed, there are no problems regarding the occupation of block sections.

Germany

When planning new signalling boxes, the new train length has to be considered for the occupation of several block sections by one train. For the 835 m trains between Maschen and Padborg, all block sections and signalling boxes were checked. Even in Hamburg, were one 835 m train occupies up to four block sections because of its length, it could be shown within a simulation at an industrial technology centre, that there is no risk of unsafe conditions.

Estonia

In Estonia the distances between route (block) signals are 3 km so that there are no problems concerning the occupation of block sections.

4.11 Counting capacity of axle counters

Longer trains allow more wagons and more axles in one single train. Axle counters have a limited counting capacity depending on their type of construction. With exceeding the maximum countable vehicle axles (counter overflow), an incorrect track release has to be expected.

France

In France axle counters are not used on sections where longer trains run.

Germany

In Germany, the maximum number of axles is limited by a Regulation to 250. Different types of axle counters are used in Germany. The oldest mechanical types can only count maximum 256 axles. Because of the risk of exceeding the number of 256 axles in one 835 m train, these types of axle counters were replaced on the relation between Maschen and Padborg. The new type of mechanical axle counters can count up to 384 axles.

Poland

There is no problem with axle counters in Poland. The maximum number of axles is limited by an internal regulation to 350 (in Poland 1 axle = 5 m). There will be no problem with the speed, too, because axle counters are adapted to 300 km/h lines.

4.12 Safe occupation of block sections

Railway systems in Europe are based on a block system where each block section as a defined and secured section of the infrastructure is covered by a block signal and can be occupied by one train only. This basic principle is the same throughout Europe, but systems vary in their technical layout and details.

Germany

Every block signal has to be installed in a defined minimum distance to the next *hazard point* in order to provide a length in case a train passes a red signal by accident. Usually this length is 200 m but there are some variations depending on the gradient.

At block signals on the free line (outside the stations), which are only for the regulation of train headways and are longer than 950 m, it is allowed for capacity reasons to put the train detection device not 200 m but 50 m behind the signal. This is possible because the train will normally stop at the next signal and with a length of 950 m the block section is long enough to provide the necessary 200 m safety gap.

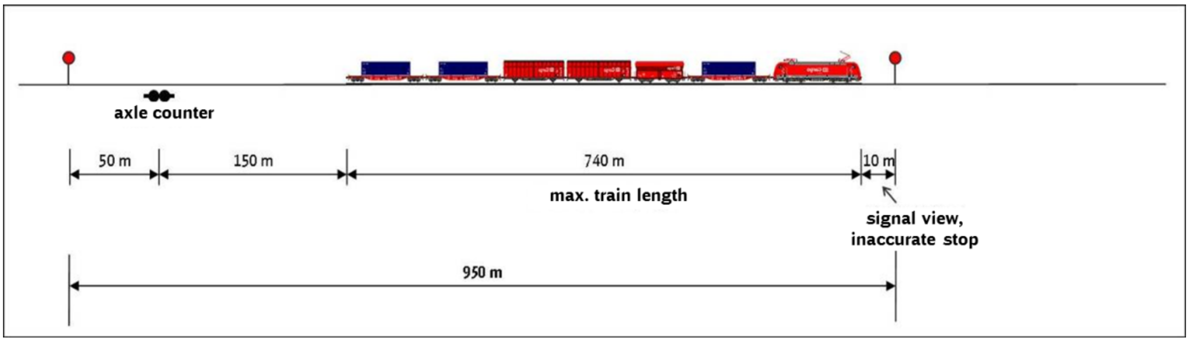

Figure 14: 740 m train in a 950 m long block section (source: DB Netz AG)

With train lengths of more than 740 m, it is no longer ensured that at these block sections (over 950 m) the hazard point distance of 200 m is free from vehicles, if the train detection device is already 50 m behind the signal.

The hazard is constituted by the fact that the hazard point distance is not always technically free checked with its whole length.

For 835 m trains from Padborg to Maschen, the train detection devices in block sections with lengths between 950 and 1,065 m were moved from 50 m to 200 m behind the signal.

4.13 Level crossings

Level crossings have to be analysed, as the train length is one parameter in the technical layout. Depending on the technical layout, adaptions could be necessary.

France

Infrastructure studies were only done for equipment placed at the rear of the train impacted after releasing the brake (elasticity).

Germany

During the preparations for 835 m trains between Padborg and Maschen, several issues relating to technically secured level crossings were identified, which depend on the train length:

- **Train stop on the level crossing**

A train stop on a technically secured level crossing can always bring additional risks, when the automatic level crossing switches off (e. g barrier opened, signal lights off) even though there are still rail wagons on the crossing.

For longer trains the section between two level crossings or a level crossing and a following signal can be too short to clear the level crossing in case of a stop at the next signal or level crossing.

- **Backward switching on**

When a train has to stop at a signal or in front of a level crossing, the backward sign on has to be obviated. Therefore, it is not allowed to stop over an active make-contact (for the opposite direction), because a backward switching on could occur.

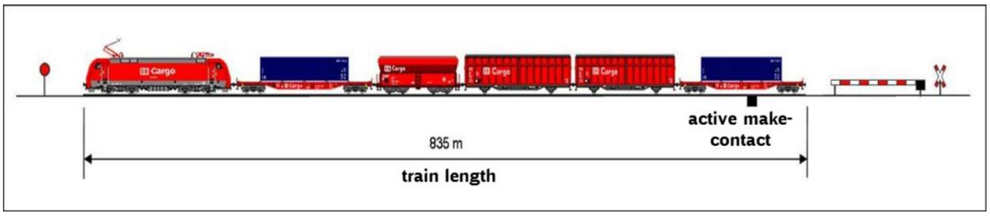

Figure 15: Backward sign on (source: DB Netz AG)

One problem of an unexpected long closure time of the level crossing could be that the road traffic passes the level crossing while it is saved (e.g. driving around barriers) without knowing whether there is another train coming or not.

- **Concurrent activation of make- and break-contact**

At level crossings designed for 740 m trains, the usage of longer trains could have the effect that make- and break-contacts of the same level crossing are activated at the same time. Some versions of automatic level crossings cannot guarantee safe conditions in this situation. The level crossings could switch off too early (e. g barrier opened, signal lights off).

It has to be checked for each automatic level crossing with a critical status how far a concurrent activation of make- and break-contact could happen and whether it causes an additional risk.

- **Closure time**

The longer the trains are, the longer the closure times will be when they pass level crossings. When there is a high density of traffic on a line, closure times could be very long. An orientation value of a maximum closure time of a level crossing is 240 sec. After that time, a level crossing should be opened in order to avoid an illegal passing of the level crossing by road traffic (e.g. driving around barriers).

4.14 Hotbox detection and treatment

Train length is one parameter to calculate the minimum range between the hot box and the dedicated stop signal. Therefore, a check of the existing distances is required.

If the number of train axles exceeds the maximum axle counting capacity of the hotbox detection, it could be that overheated or warmed axles would not to be properly detected.

France

In some cases the hotbox detector must be moved or fully automated in order to have a sufficient distance between it and the dedicated stop signal. The detection must be automatically followed by the train stop. The greater length of trains requires a revision of their location based on the availability of long sidings; the spacing between hotbox detectors is standard; step by step, much of the hotbox detectors might need to be moved, and on this occasion renovated (many untimely alerts). To avoid double work, the detectors implementation program should be designed in a shared long-term perspective between the IM and the RU.

Germany

Between Padborg and Maschen, the distances from hotbox and stop signal are all long enough for 835 m trains. The axle counting capacity of the hotboxes is also big enough for the longer trains. There were no measures needed.

Switzerland

During the studies on longer trains it was understood that the facilities for intervention (e.g. sidings after hot box detection) would also have to be modified for longer trains (location, track length and equipment). Incidents would have to be managed within the specified time and during regular operation of other trains.

Poland

The distances between hotboxes and stop signals are all long enough for trains longer than the Polish standard 750 m. But there is a problem to find an adequate place to stop the train to get off the faulty wagon after hot box detection. All upgraded station tracks (main and side) are adapted to the maximum allowed length of freight trains in Poland, to 750 m.

4.15 Weight restrictions on bridges

The cruised tracks and bridges have to be suitable for longer trains and their permissible axle loads, loads meters (according to the rules of train formation) and the changed load spreading on a bridge.

France

Checks revealed that there should be no impact on bridges like resilience, risks of sliding the tracks by braking.

Germany

For the line Padborg–Maschen, checks were carried out to determine whether measures were needed for the *Rendsburger Hochbrücke*. Static calculations have shown that there is no need for special restrictions for 835 m trains regarding the bridges.

Estonia

A loading scheme for bridge design exists: A Combination of 350 kN and 330 kN axles and trains with 140 kN/m weight per meter.

The used rail type is 60E1 350HT. When it comes to sleepers the spacing is 0.54 m (1,840 sleepers per 1km). Concrete sleepers and fastenings are designed for 32 t axle load. With wooden sleepers hardwood is preferable. Turnouts have to be 1/11 angle or longer. Regarding rail welding, flash-butt welding is preferable and a high quality of aluminium-thermic welding important.

Poland

A loading scheme for bridge design is based on the line’s category defined by reference wagons and load models in PN-EN 15528 and it depends on technical characteristics and conditions. There are no lines dedicated for longer or heavier trains in Poland (except one case described in 3.9). The length of train doesn’t increase the permissible axle load or load meters, but the weight does. Implementation of heavier trains would be limited by the weight restrictions on bridges. On the network managed by PLK currently there are:

- 59 structures that have limited load-bearing capacity
- 71 that are close to a load-bearing capacity limit

But these values are referred to the speed which is valid on the line. Reducing the speed limit we can increase the weight of the train that may pass the bridge. Generally the structures in Poland are modernized to 22.5 t. On lines which are dedicated to freight trains, bridges and other structures are modernized to 25 t.

4.16 Fixed installation of electric traction (energy equipment)

The impact of longer trains on existing equipment must be checked in order to accept the increase of energy supply, e.g. capacity, overheating, electromagnetic problems and return of traction current.

France

Measures to be taken are: strengthening of installations (substations) and operational measures (additional spaces between trains, limitation of power). Increasing power of substations also causes an upgrade of the transmission lines.

Upgrading power stations has to be particularly studied for heavy trains, as it is not always possible to ensure that two heavy trains will not be in the same area at the same time.

Germany

The layout of the electric power supply can have consequences concerning capacity or rules of operation. For the line between Padborg and Maschen, the following hazard was identified:

In cases of longer trains with one or several electrical traction units at the front in pushing mode with an electric traction unit at the back of the train, a bridging of the electrical distance separation by the trailing pantograph could happen, in case of minor distances between the supply district boundaries and the main signal. This circumstance could possibly cause a catenary burn.

4.17 Approval processes

The operation of longer trains has to be approved by the national safety authorities. Experiences have been made in France for the operation of 850 m long trains and in Germany for the 835 m long trains.

France

The MaxiPerfo workshop was the starting point of the investigations concerning longer trains.

The approval of 850 m trains in France was made on the basis of sound business models of several RUs, internal agreements and studies and inspections.

Two safety reports have to be done. The existence of appropriate solutions to the infrastructural issues had to be detailed by the IM; the solutions to the train-related issues had to be provided by the RU. The main focus was on the train issues of braking and the longitudinal forces within the train.

Regular meetings took place every month with different partners of the long train project which includes representatives of the government, the safety authority, the IM and several RUs. The actual status and problems could therefore be discussed by all responsible entities. During one of these meetings, the government set a date to start the regular operation of 850 m trains, thus giving political support to the project.

Germany

For the operation of the 835 m long trains, a proof of equal safety had to be established. This was done on the basis of the process of train operation, analysing every step from the building of the train to the separation of the train at the end of the transport. All identified issues were analysed in today’s operation with 740 m (reference system) and the possible hazards when extending the train length to 835 m. Measures had to be identified to reach the same safety level as today. The variety of subjects could only be handled in a close cooperation between 35 different departments of DB AG.

The bilateral communication with the German railway authority (EBA), while at the same time developing the proof of equal safety, including the detailed discussion of relevant hazards and the effectiveness of the chosen measures, ensured the acceptance of the solutions.

In addition to the proof of equal safety, the capacity effects of the 835 m trains and necessary measures to ensure an equal quality of operation had to be discussed with the railway authority as well.

Estonia

In Estonia, longer trains do not have to be separately approved by the NSA. The possibility of operating such long trains (e.g. max parameters) has been already foreseen in the operating rules and network statement of the infrastructure which both documents have to be approved by the NSA before they are put into force. All the following activities are coordinated and regulated by the traffic management and forming plans of the train.

5 Business cases

Summary

Business cases have to be developed based on defined traffics and relations. Funding for necessary adaptations of infrastructure does not fit in today's categories of replacement investments, maintenance or investment in new lines. Stakeholders have both national railway and external background with varied interests and views on the topic of longer trains. Although this might mean a long process, it is noticeable that for each stakeholder a lot of positive effects exist. Due to the diversity in the working group, there have to be two kinds of business case models, economic and socio-economic. The influencing factors for each kind have been defined in this chapter.

Business cases have to be developed on a case-by-case basis taking into account the specific framework conditions:

- market potential and volume of traffic;
- operational concept;
- weight of goods to be transported (mass restrictions);
- traffic mix and timetables;
- given infrastructure (track, stations and marshalling facilities) and extent of necessary adaptions;
- rules of operation.

The results may vary and longer trains may not be suitable for every traffic or relation.

Longer freight trains require investments in infrastructure. A funding is necessary for the described adaptions of the existing infrastructure which do not fit in today's categories for:

- replacement investments;
- maintenance;
- investment in new infrastructure.

A special program for longer trains could be a possible way of funding.

5.1 Stakeholder analysis

First of all there has to be an analysis of important stakeholders for longer trains.

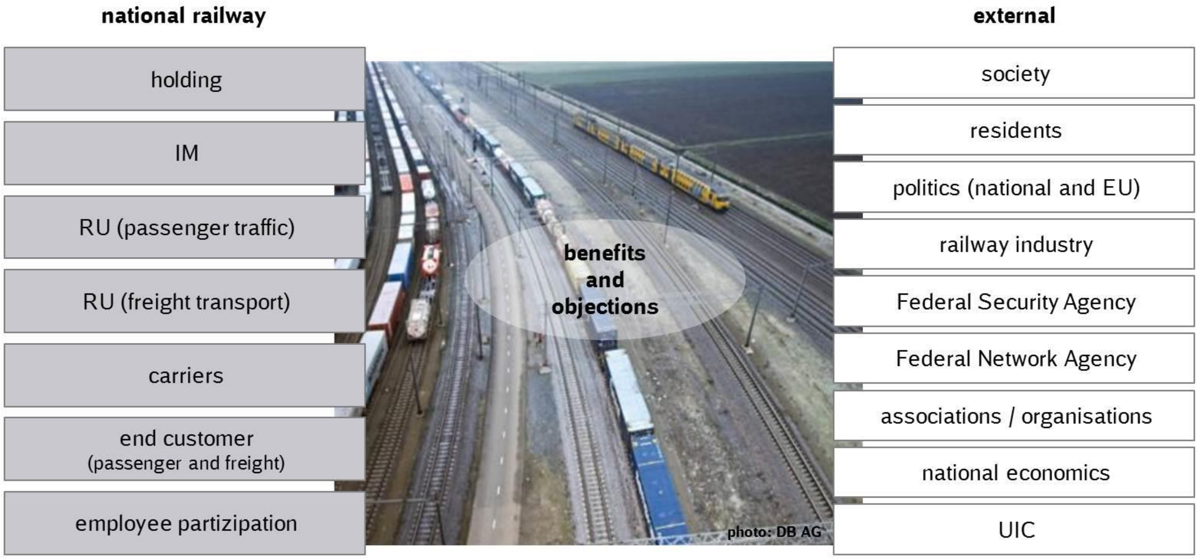

Figure 16: Important stakeholders (own chart)

A first estimation of the relevance for the various stakeholders was made in a workshop of the working group. Results are shown as some examples:

- For national politics the positive aspects of longer trains could be the chance to create an interoperating European railway system where an increased capacity for economic growth or less funding for infrastructure is possible, whereas the increased fear about noise, the effects on punctuality of passenger trains and maybe density same as disruption could be seen as negative aspects for this stakeholder.
- For the EU politics it would be very positive to have an interoperating European railway system. The goals of the white paper will be reachable (Shift²Rail) and an increased capacity for economic growth can be realized.
- The stakeholder RU passenger traffic could have positive effects because of more capacity (fewer trains, more gaps) with the fact that freight is concentrated in fewer trains. But the negative effect derives from the hindrance of passenger trains because of the longer freight trains running slower than short trains.
- On the opposite RU freight transport could have positive effects in economics (less drivers, less loco), less path charge (if no special fee would be implemented), more capacity (less trains, more gaps) and especially more freight in one train. Negative effects for RU freight transport might be in less frequency and more handling costs.
- Through the eyes of an IM the positive effects could be fewer trains on the tracks so that there could be more time windows for maintenance, furthermore new modern infrastructure and the possibility to do more exact planning. The negative effects could be that only few stations for passing exist and therefore a problem of operation in case of delay may occur. It could be investment headed and there might be eventually less income of path charges if there would not be established a special charge.
- For the society, the results of the workshop group found are that on one hand it could

be positive that lower greenhouse gases would be emitted, less traffic and therefore more safety on the roads created and noise per ton reduced. On the other hand side it could be negative that the noise in urban areas could increase, the longer sidings might need additional land use.

- To residents especially the reduced number of trains, less pollution, less traffic jams on roads and less waterborne traffic could be very positive, whereas the longer waiting time at level crossings and more noise/train could be negative.
- Finally for the end (passenger and freight) customer longer trains could have positive effects in reduced lost per ton, optimized usage of assets and better planned logistics, but negative effects in the eventual cause of delays to passenger traffic, the need for adjustments from the industry and the increased risks in the logistics chain in case of a problem.

In conclusion there are many different stakeholders with even more varied interests and views on the topic of longer trains. Although the variety might cause a long process, it is noticeable that for each stakeholder a lot of positive effects exist.

5.2 Factor of business cases

In a second step the possible factors with influence on business cases were collected. The collected ones are shown below:

Financing IM

- necessary investment in infrastructure
- assessment of infrastructure
- possibilities for longer trains in shunting yards and sidings
- financial contribution of EU
- financial contribution of countries

Financing RU

- coupling system
- braking system
- investment in *rolling stock* (e.g. loco remote control)

Technology

- capacity of electric substations
- sufficiently powerful traction
- properly working signaling system
- coupling system
- braking system
- loco remote control

Market

- market demand and forecast of demand
- horizontal collaboration
- infrastructure offer
- used length today vs. length offered today

Political (EU)

- decisions of other IMs/nations

Capacity

- capacity constraints
- increase in capacity
- enhanced shunting yard and shunting yard handling capacity
- solving bottlenecks with small investments
- line speed

Economy

- lower costs and cheaper production of freight traffic
- less drivers and locos
- more traffic to rail
  - more income for IM and RU
  - more maintenance on railways
  - less road maintenance
- goal: win-win situation for both IMs and RUs

Charges

- less charges (expenses) for RU
- less charges (income) for IM
- special charge for longer trains

Operation

- more perturbations in operation
- adapted operational rules
- measures for safe operation
- operational costs for IM and RU
- potential of disruption effects on other trains

- skilled workforce (e.g. drivers)

For **Environment**, longer trains involve less environmental effects.

- noise and vibration reduction
- effect on road traffic

On this basis, the three most important factors with influence for the business case from the participants' point of view were:

- market demand
- capacity constraints
- investments IM

To cluster the factors the table below sorts them into economic and socio-economic factors, whereby economic factors purely touch the economical view of the company and the socio-economic factors have an impact on both company and society:

Topic	Factor	Economic	Socio-economic
Financing IM	necessary investment infrastructure - assessment of infrastructure	x (once-only costs IM)	x
Financing IM	necessary investment infrastructure - possibilities for longer trains in shunting yards and sidings	x (once-only costs IM)	x
Financing IM	financial contribution of EU	x (once-only benefits)	x (once-only costs public)
Financing RU	coupling system	x (once-only costs for RU)	-
Financing RU	braking system	x (once-only costs for RU)	-
Financing RU	investment in *rolling stock* (e.g. loco remote control)	x (once-only costs for RU)	-
Technology	capacity of electric substations	x (once-only costs IM)	x

Topic	Factor	Economic	Socio-economic
Technology	sufficiently powerful traction	x (once-only costs RU)	x
Technology	properly working signaling system	x (once-only costs IM)	x
Market	market demand and forecast of demand	x (target rate of interest IM)	x
Market	horizontal collaboration	x (constant costs IM) x (constant benefits IM)	to be checked
Market	infrastructure offer	x (constant costs IM)	x
Market	used length today vs. length offered today	x (constant benefits RU)	x
Political (EU)	decisions of other IMs/nations	x (date of decision IM) x (period under consideration IM)	x
Capacity	capacity constraints	x (constant costs IM / RU)	x (constant costs passenger service)
Capacity	increase in capacity	x (constant benefits IM / RU)	x (constant benefits passenger service)
Capacity	enhanced shunting yard and shunting yard handling capacity	x (constant benefits IM / RU)	x
Capacity	solving bottlenecks with small investments	x (constant benefits IM / RU)	x (constant benefits passenger service)
Capacity	line speed	x (constant costs IM)	x (constant costs public)

Topic	Factor	Economic	Socio-economic
Economy	lower costs and cheaper production of freight traffic	x (constant benefits IM / RU)	x (constant benefits public) x (constant benefits environment)
Economy	less drivers and locos	x (constant benefit RU)	x (constant costs public due to increase of unemployment) x (constant benefit public due to increased productivity based on the assumption that the drivers work with something else)
Economy	more traffic to rail à more income for IM	x (constant benefit IM)	x
Economy	more maintenance on railway	x (constant costs IM)	x
Economy	less road maintenance		x (constant benefits public)
Economy	win-win situation for both IMs and RUs	x (constant benefits IM /RU)	-
Charges	less charges RU (expenses)	x (constant benefits RU)	-
Charges	less charges IM (income)	x (constant costs IM)	-
Charges	special charge for longer trains	x (constant benefits IM) x (constant costs RU)	-
Operation	more perturbations in operation	x (constant benefits RU)	to be checked
Operation	adapted operational rules	x (once-only costs IM / RU)	to be checked

Topic	Factor	Economic	Socio-economic
Operation	measures for safe operation	x (once-only costs IM / RU)	to be checked
Operation	operational costs for IM and RU	x (constant costs IM / RU)	to be checked
Operation	potential of disruption effects on other trains	x (constant costs IM / RU)	x (constant costs passenger service)
Operation	skilled workforce (e.g. drivers)	x (constant costs IM / RU)	x (constant benefits public due security of employment)
Environment	noise and vibration reduction	x (once-only costs IM / RU)	x (once-only costs public) x (constant benefit public due to emissions reduction)
Environment	effect on road traffic		x (constant benefits public) x (constant costs road traffic) x (constant benefits environment)
Environment	effects on passenger traffic		x

Table 4: Categorization of factors for business case models

5.3 Determination of the factors

There are huge differences between the participating countries and with them goes a wide range of values. For example in Hungary a standard path in freight traffic (300 km, 749 m train length, 1,600 t) costs up to EUR 825, while with EUR 355 in Sweden the costs are a lot lower. Another example for the diversity of circumstances is the estimation for the value of one minute delay in freight and passenger traffic. The range between the countries is from EUR 0.64 to EUR 4.40 regarding freight traffic. For the passenger traffic the range goes from EUR 0.64 up to EUR 13.00. While in some countries an additional one meter of a noise reducing wall costs around EUR 120 per meter, in other countries it costs over EUR 700. It is clear that no overarching values can be found. Because of different premises and circumstances in the countries a case by case analysis for each line in the different country has to be done.

5.4 Models of business cases

All participants agreed that requirements for two different types of a business case model exist:

a) economic evaluation

b) socio-economic evaluation

The decision is to show a model for the socio-economic effect as well as the economic effect due to the different methods of the IM's in part taking countries.

For example DB Netz AG, SBB, MAV and PLK are doing their business cases for the economic effect on their own while the socio-economic business cases are done by state organisations.

Economic model	Socio-economic model
SBB (state: socio-economic)	Banedanmark (but political decisions important)
DB Netz AG (state: socio-economic)	PLK (projects financed by EU)
MÁV (between ministry and IM, different financing: EU + state)	SNCF Reseau
PLK (projects financed by state)	Trafikverket (60 years)

Table 5: Economic vs. socio-economic model at IMs

Economic approach

As an example for the economic model the method of DB Netz AG will be shown. The factors mattering for the input are:

- once-only benefits
- once-only costs
- constant costs
- constant benefits
- date of decision
- date of initiation

- period under consideration (depreciation period)
- target rate of interest

After the economy calculation by DB Invest (the used tool at DB Netz AG) the different kinds of output are:

- net present value
- annuity
- time of amortization (breakeven point)
- return on investment

Afterwards, in the period under consideration, continuation and several project options have to be analysed and compared.

In detail, the net present value for RU's includes locomotives & driver, national charges, international charges, additional shunting and invest remote control. For the IM's it includes income track changes, own capital resources of construction works, additional maintenance and reselling free paths.

The whole process is summarized in the graphic following:

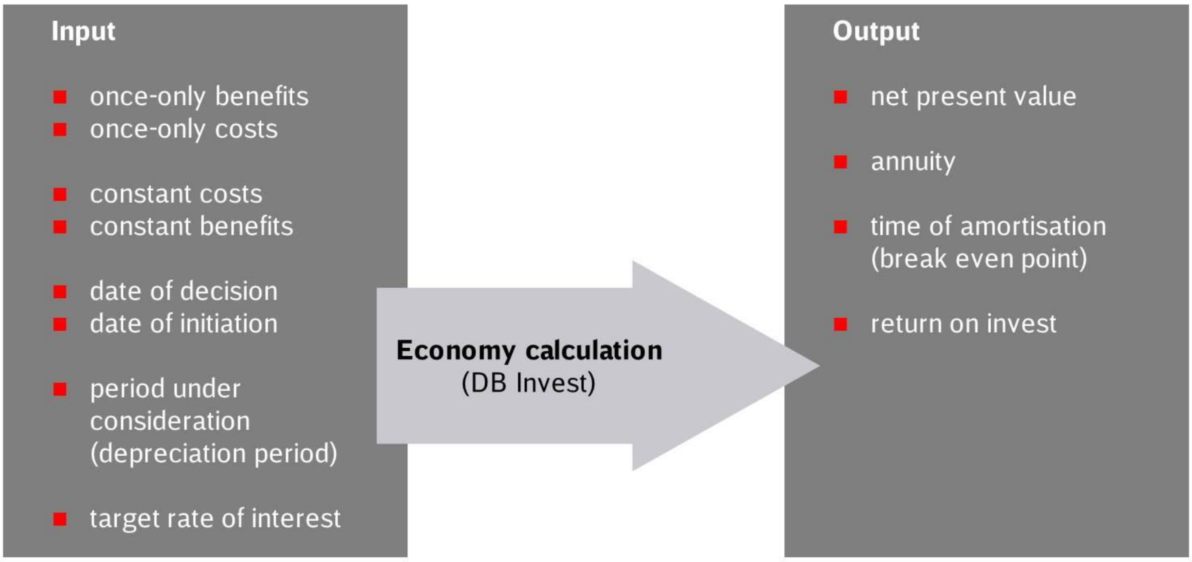

Figure 17: Method of economy calculation at DB Netz AG (source: DB Netz AG)

It is particular important to note that the economic effect has to be balanced so that a win-win-situation for both RU and IM can be created. One possibility could be to charge higher track costs for the track access for longer trains.

Socio-economic approach

"Economic efficiency is assessed using analysis weighing the costs against the benefits of different measures.

In order to make such analyses in Sweden, traffic forecasts, effect relationships, socio-economic methodology, calculation values, as well as forecasting and analysis tools are used. How this is connected is described below:

- **traffic forecast**

Traffic forecast conditions such as income, population, industry structure and infrastructure are used as input to a traffic forecast model. There are such models for both passenger (Samper) and freight (Samgods). A traffic forecast model results in a traffic forecast. A traffic forecast describes the future development of traffic (for example, expressed in number of vehicles and vehicle kilometres) and future demand for travel and freight.

- **socioeconomic calculation (cost-benefit analysis, CBA)**

Traffic forecasts can then be used as an input together with the conditions and calculation values of different calculation tools. Calculation tools in turn contain various power connections, power models and elasticity values. The result of a calculation tool is a CBA that report effects, socio-economic benefits and costs same as profitability measure. Basic calculations of effects (e.g. for road safety and environment) can also be done using the Swedish Transport Administration's response relationship and effect models.

- **cost-benefit analysis and comprehensive impact assessment**

A CBA is not enough to describe all the effects of a measure on society. Some impacts can be quantified but not valued in terms of money, while other effects are also difficult to quantify. In a complete economic analysis also the difficulty to evaluate effects must be included. To make an overall assessment of the socio-economic profitability, it is complemented with the socio-economic calculation with assessments of the non-priced effects.

This is done in a comprehensive impact assessment which is a method and a template to describe the impacts of a measure in a coherent and structured way. In an overall impact assessment both priced and non-priced effects and distributive effects are described. Additionally the measure's contribution to the transport policy objectives is assessed."[7]

As an example for possible factors of a socio-economic business case the factors mattering for the input at Trafikverket in Sweden will be shown [8]:

- base for real prices (prices adjusted for inflation)
- year of discounting, i.e. the time defined as present time
- year of starting the construction of infrastructure investments

[7] source: http://www.trafikverket.se/for-dig-i-branschen/Planera-och-utreda/Planerings-och-analysmetoder/Samhallsekonomisk-analys-och-trafikanalys/Analysmetod-for-samhallsekonomisk-effektivitet

- base year for the forecast of future traffic
- first and second year of forecast
- year of *breaking the growth*
- growth of traffic
- distribution of the investment cost over construction time
- construction time
- life time of investments and evaluation periods
- social rate of discount
- cost data relevant to the CBA and treatment of *sunk costs*
- investment costs in the reference scenario
- indirect taxes
- marginal cost of public funds
- rate of interest and rate of return in business calculations
- update prices - new base of prices and new real price level
- deflation of prices and change of base year of real prices
- changes in real prices over the evaluation period
- cost of investment
- operation and maintenance
- value of reliability of travel time and delays
- value of travel comfort in public transport
- value of delays in transport of goods
- safety and cost of accidents
- cost of noise
- cost of air pollution
- cost of global warming
- vehicle operating costs for transport of goods
- transport across the national border
- land use
- indirect effects outside the transport market (wider economic impacts)
- other issues
    - valuation of potential for future benefits
    - valuation of city environments

As another example for a method for business case development the method of PLK in Poland will be shown.

In Poland there is a kind of duality in models of business cases. In one case it contains an economic approach, in the other case a socio-economic. It always depends on financing. Regarding the investment financed from state budgets it is always an economic model. The factors mattering for the input are costs and benefits. And the output is time of amortization and return on investment (higher speed, more comfort for passenger).

Due to investments financed from EU funds (Cohesion found or any other regional financing programs) always the socio-economic approach has to be chosen. Such an investment must become listed on the list of implementation. To be on this list projects have to go through a very detailed evaluation where many factors are taken into account. The factors mattering for the input are economic and social.

The economic ones are:

- technical/technological feasibility
- financial viability
- reality of calculated indicators
- project sustainability

Of course costs and benefits of IM, time of amortization and return on investment are taken into account too. All projects that fulfil these criteria are qualified for the realization. However, the order of realization determined social factors. These factors are e.g.

- environmental friendly transport
- development of TEN-T network and multimodal transport
- elimination of problems on the job market
- international promotion of the region
- kind of innovations will be introduced by investment

If a project is financed from regional founds, the specific local criteria are introduced in the evaluation. That may cause additional requirements for larger noise and vibration reducing or requirements related to protect the landscape.

After the verification of the project in accordance with all these criteria, the next step is public consultation with many institutions and sometimes for small local investments with the local community.

In Denmark traditional economic calculations are done when planning projects. Additionally the Ministry of Finances demands a socio economic calculation for bigger projects, following a specified modal from the Ministry. The modal is comprehensive and detailed. Time is important and currently freight is given a value of EUR 0.52 per ton-hour. An international interest is used, today 4 % for the first 35 years.

All details of the project are calculated in present value (NPV) and total project interest is calculated.

Included in this calculation are many factors, besides time are investments, maintenance, operating expenses and a lot of environmental effects and costs (however, with relatively low values).

Also more complicated economic factors are included, such as a tax distortion effect.

Comparison of the Danish model with similar models used in the other European countries will be comprehensive.

An example for a list of factors for socio-economic evaluation is:

- energy consumption
- traffic safety
- carbon dioxide emission
- air pollutants
- traffic noise
- dissection of landscape and land consumption

6 Approach to longer trains - recommendations

Summary

Longer trains require coherent changes both from the RUs and the IM. Due to the cost and the long life cycle of infrastructure, decisions to implement longer trains have to be well prepared. Feasibility studies should start with investigating the market potential and cover all technical, operational and financial issues. Proof of feasibility in all three aspects should be given before any investment decision is done. Solutions from outside of Europe are not adaptable to European conditions.

Longer trains have to be operated at the same safety standards as today's trains. Proof of equal safety has to be established and accepted by the railway authorities. For the existing relations with longer trains, this has already been done on a national level.

6.1 Feasibility study

Longer trains require coherent changes from both, the RUs and the IM, including: scheduling, rescheduling, incident management, infrastructure in lines and in marshalling yards, access pricing, train dynamics, and rules and standards.

Due to the long life cycle of infrastructure and the costs of the adaptions, the decision to realize longer trains has to be well prepared. Experience shows that a step-by-step approach is suitable concentrating on selected traffics or relations instead of aiming at a complete network from the start.

Necessary feasibility studies should start with an investigation of the market potential for a given traffic and/or relation. This includes analysing the goods transported, the operational scenarios and the rolling stock, as well as the forecast for the traffic and the competitive situation. Activities can thus be concentrated on promising traffics and/or relations.

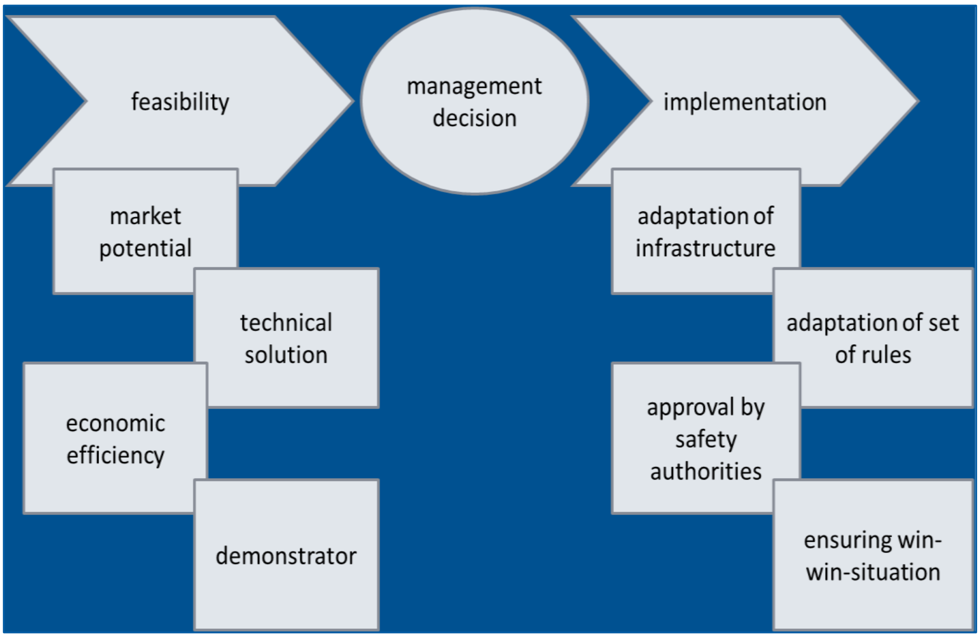

Figure 18: General approach to longer trains (own chart)

The next step will then be the development of technical solutions for the operation of longer trains. Depending on the pursued train length, this will include not only solutions and adaptions on the infrastructure side, but also on the equipment of the existing rolling stock. The analysis has to look at the whole railway system. Solutions have to be found in a way that allows a safe operation of longer trains as well as a high quality of operation. Topics that have to be dealt with are explained in chapter 4.

For the selected and analysed relation and traffic, the economic efficiency has to be proven. The business case can be established on the basis of the results on market potential and technical solutions. Measures can be derived to ensure a win-win-situation for RUs and IMs (see chapter 1.4).

The last part of the feasibility study can be a demonstrator showing the feasibility by test drives or a restricted number of trains in operation. This will generally be done using the given infrastructure, thus requiring special rules of operations.

Based on the results of the feasibility study, a decision to realize longer trains can be reached. The proof of the technical, operational and economic feasibility has to be given.

6.2 Project for implementation

If the decision is made to realize longer trains, it is recommended to set up a realisation project. The different measures have to be taken in a coordinated way, including:

- adaptation of the infrastructure;
- adaptation of the set of rules;
- approval by safety authorities;

- inclusion of longer trains in the network statement;
- ensuring win-win-situation;
- definition and communication of operation set of rules;
- preparation of the rollout;
- accompanying communication.

7 Abbreviations

BMF	Federal Ministry of Finance Austria ("Bundesministerium für Finanzen")
BMVIT	Federal Ministry for Transport, Innovation and Technology Austria ("Bundesministerium für Verkehr, Innovation und Technologie")
CEF	Connecting Europe Facility
CEO	Chief Executive Officer
CER	Community of European Railway and Infrastructure Companies
CHF	Swiss currency ("Schweizer Franken")
DB	German Railway ("Deutsche Bahn")
DB Netz AG	German IM
EBA	German Railway Authority
EPSF	French Safety Authority
ERTMS	European Rail Traffic Management System)
ETCS	European train control system
G	braking mode for freight trains
GZ	freight train ("Güterzug")
HP	high performance
IM	Infrastructure Manager
kN	Kilonewton
KVB	French linear and safety control system ("contrôle de vitesse par balises")
LCF	longitudinal compressive forces
LL	special braking mode for freight trains ("Lange Lok")
LS	limited supervision (ETCS mode)
LZB	continuous train control system ("Linienförmige Zugbeeinflussung")
MÁV	Hungarian Railway ("Magyar Államvasutak Zrt.")
ÖBB	Austrian Federal Railways ("Österreichische Bundesbahnen")
P	braking mode for passenger trains
PKL	PKP Polskie Linie Kolejowe s.a
PZB	punctual train control system ("Punktförmige Zugbeeinflussung")
RAG	Railway undertakings advisory group

RFF	French Infrastructure Manager ("Réseau Ferré de France")
RFL	Reliable Freight Logistics
RU	Railway Undertaking
SBB	Swiss Federal Railways ("Schweizerische Bundesbahnen")
SNCF	French Railway ("Société Nationale des Chemins de fer Français")
TAG	Shunting yard advisory groupTEN-T Trans-European Transport Networks
TOC	train operating company
TRV	Swedish Transport Administration ("Trafikverket")
TSI	Technical Specifications for interoperability
UIC	International Union of Railways ("Union internationale des chemins de fer")
ZL	train length ("Zuglänge")

8 Figures

9 Tables

10 Text sources / references

[1] ETIF, 2012

[2] CER, Rail Freight Status Report 2013

[3] European Commission, White Paper on Transport 2011

[4] Deutsche Bahn AG: Mehr Verkehr auf die Schiene – Wirtschaftlicher Betrieb mit Güterzügen bis 1.000 m, Förderkennzeichen: 19 G 6012 A – C, Projektabschlussbericht Verbundprojekt GZ 1000, München, 12.05.2010

[5] CER Final Position Paper on the Review of the TEN-T Policy, 28 February 2012

[6] Longer / heavier trains: CER Principle Position – Discussion Paper, 04.05.2011

[7] UIC, Heavy and/or Long Trains, Paris, February 2013

[8] Trafikverket; Samhällsekonomiska principer och kalkylvärden för transportsektorn: ASEK 5.2; Version 2015-04-01; Kapitel 20 English summary of the ASEK Guidelines

[9] Shift²Rail Joint Undertaking, Multi-Annual Action Plan, October 2015

11 Authors of this paper

Michael SCHULTZ-WILDELAU (DB Netz AG)

Angela LANG (DB Netz AG)

Christian WÖRMANN (DB Netz AG)

Rudolf KOLLER (ÖBB Infrastructure)

Regina TROGER-GRUBER (ÖBB Infrastructure)

Philippe WRIGHT (SNCF RESEAU)

Eric GUENTHER (SNCF RESEAU)

Joachim JOOS (SBB Infrastructure)

Heike HARZBECKER (SBB Infrastructure)

Arvo SMILTINSH (EVR)

Tomas ARVIDSSON (Trafikverket)

Anders EKMARK (Trafikverket)

Jimmy JOHANSSON (Trafikverket)

Hans Ege JØRGENSEN (Banedanmark)

Barna BÉRES (MÀV)

György FEJÖS (MÀV)

Iwona ZUBILEWICZ (PLK)

Hans BESSER (CER)

Disclaimer

Community of European Railway and Infrastructure Companies (CER) AISBL

Avenue des Arts 53

B-1000 Brussels

Belgium

Tel +32 2 213 08 70
Fax +32 2 512 52 31
contact@cer.be

About CER

The Community of European Railway and Infrastructure Companies (CER) brings together more than 70 railway undertakings, their national associations as well as infrastructure managers and vehicle leasing companies. The membership is made up of long-established bodies, new entrants and both private and public enterprises, representing 73% of the rail network length, 80% of the rail freight business and about 96% of rail passenger operations in EU, EFTA and EU accession countries. CER represents the interests of its members towards EU policy makers and transport stakeholders, advocating rail as the backbone of a competitive and sustainable transport system in Europe. For more information, visit www.cer.be or follow us via Twitter at @CER_railways.

This CER document is for public information.
Although every effort is made to ensure the accuracy of the information in this document, CER cannot be held responsible for any information from external sources, technical inaccuracies, typographical errors or other errors herein. Information and links may have changed without notice.