“Scandria Railway Corridor Performance”
Baltic Sea Region Project #026
“Scandinavian-Adriatic Corridor for Growth and Innovation”

Work Package 3 Quality of Transport Infrastructure

Action 2 Improvements in rail traffic

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Brief Description of the output

The rail market share in the corridor between Scandinavia and Germany is less than on road and air. Thus, there is potential for significantly increased transport volumes by rail to contribute to a sustainable transport system. There are weak links in the infrastructure and in the operating principles. In short time changes can be done by unifying loading gauges and train lengths. Discrepancies of technical standards exist between the various national railway networks. For new construction and upgrading of infrastructure, the opportunity to apply best practice standards should be seized. Our proposal is that the planned Fehmarn Belt link and its connecting lines should generally match or surpass the highest of German, Danish and southern Swedish standards which already has been implemented on the Öresund bridge. In the long term perspective building of dedicated high speed lines seems to be the right solution if the railway is to have a significant share of passenger transport as well as freight transport market.

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Summary of Methodological Approach

Questions to be answered:
- What are the weakest links in the rail transportation system in the Scandria corridor?
- Investigation of infrastructure performance, Benchmarking of the corridor functionality, investigation of best practice and proposal of future investments and operating principles.
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Preface

This report is made for the Scandinavian – Adriatic Corridor for Growth and Innovation (Scandria) project, which is an EU-financed project in the Baltic Sea program. The aim of the project is to increase the exchange of knowledge between the regions in the Scandria corridor and create prerequisites for a positive development of trade and transports between the regions.

This report is the final issue of a report from the Railway Group at KTH, Royal Institute of Technology in Stockholm, Sweden. Project leader is Bo-Lennart Nelldal, who has written this report together with Hans Boysen (KTH). Facts from other projects have been used; some of these come from Gerhard Troche (KTH), Jakob Wajsman (Trafikverket) and Lars Ahlstedt (European Rail Consult).

The authors are responsible for the conclusions in this report. The first draft was published 2010-09-25 and this is the final report which has been completed with maps of infrastructure performance, conclusions and some other material.

Stockholm 2012-09-07

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Summary

The market share of freight trains in the corridor between Scandinavia and Germany is significantly less than those of trucks and ships. Thus, there is potential for significantly increased transport volumes by train, if the train services are made more attractive to the shipper. The measures outlined here would aim to raise system capacity as well as to lower costs. In general the deregulation of the freight railway is important to get a more efficient and attractive service for shippers. This has not been studied in this project but has to be mentioned.

The maximum train length has already been extended from 750 to 835 m between Hamburg and Copenhagen. Further efficiencies would be realized if these trains could also extend their operation into Sweden, primarily to Malmö and Hallsberg. Further investigation of how to handle this is needed.

Establishing a larger and rectangular loading gauge is important for voluminous goods. Considering the normal catenary heights of 5.3 to 5.5 m in Denmark and Germany, a height matching the Swedish C loading gauge at 4.83 m appears feasible. This is very important for forest products and intermodal transport of semitrailers, for which height is more important than width.

Additional freight train paths for 120 km/h can be established during daytime in areas where passenger traffic dominates. The number of wagons approved to operate empty or loaded at 120 km/h is growing steadily, making this feasible and practical.

Building new or upgrading track for 25 tons axle load will make freight rail more efficient for a wide range of commodities including intermodal. This has already been introduced on lines in Finland, Germany, the Netherlands, Norway, Sweden and the United Kingdom, as well as in the wagon fleets. In combination with raised meter loads to 8.3 tons/m between the gateways of Trelleborg, Malmö and connecting lines at Halmstad and Hallsberg, this would enable the steel industry to load its existing wagon fleet to its full capacity.

Capacity constraints in the form of single track sections exist on several of the lines in the Scandria corridor. Severe bottlenecks in Sweden and Norway include the Hallsberg-Mjöby and Oslo-Göteborg lines where double track is needed. On the West Coast Main Line double track will be nearly complete from Öxnered (near Trollhättan) to Copenhagen by 2015. The missing link for the future for freight as well as passenger traffic remains the section from Haug to Öxnered. Also the 25% grade at Halden, being twice as steep as other grades, restrict the train mass.

To minimise bottlenecks in northern Germany, existing lines connecting the planned Fehmarnbelt link need to be electrified from Lübeck to Lüneburg and Bad Kleinen to enable through operation to the main north-south corridors via Lüneburg and Ludwigslust.

The international passenger traffic in the Scandria corridor has decreased in recent decades as a consequence of the deregulation of airlines and much cheaper air travel as well as higher car ownership and investment in improved roads. The railways have not so far been able to meet the competition. In the short term there is a need for the following measures: An information system and tickets sales for all operators must be available on internet, better coordination of timetables between operators, more direct connections without change of trains and cheap offers are important for leisure travel.

In the long term there is a need for high speed connections with shorter travel times between the most important towns in the Scandria corridor – shorter than 3-4 h is necessary to compete with airplanes for
business travel. There have been investigations of dedicated high speed lines both in Sweden and in Norway and higher speed in Denmark has also been evaluated according to the Fehmarn Belt connection. There is however no common standard or strategy for high speed lines in Scandinavia.

The most important links for the Scandria passenger transport corridor are the Southern Main Line between Stockholm and Malmö/Copenhagen and the West Coast Main Line between Oslo/Gothenburg and Malmö/Copenhagen. Both lines will be connected with Germany via the Fehmarn Belt fixed link around 2021.

The Swedish Government has in August 2012 proposed to build the first part of the high speed lines between Södertälje and Linköping “Ostlänken” and Gothenburg-Borås. This can be a first step to dedicated high speed lines in Sweden which will also free capacity for freight trains and regional trains on the conventional main lines.

Significant discrepancies of technical standards still exist between the various national railway networks. For new construction and upgrading of infrastructure, the opportunity to apply bold, forward-looking standards should be seized. Our proposal is that the planned Fehmarnbelt traverse and its connecting lines should generally match or surpass the highest of German, Danish and southern Swedish standards:

- Maximum gradient 12.5 ‰. Fehmarnbelt will be connected in series with the existing Öresund link, which has 15.4 ‰ gradient in the tunnel, 15.6 ‰ gradient eastbound and 12.4 ‰ westbound on the bridge, but a parallel Kastrup freight bypass is already being proposed.
- Length of sidings for 835 m trains plus a portion of the stopping distance, e.g. 835 m + 190 m = 1015 m. In the longer term, increasing train lengths to two single trains coupled.
- Loading gauge matching the Swedish C profile of 4.83 m × 3.6 m, or if not possible reduced to 4.83 m × 3.15 m, with full width at the top.
- Axle load 25 tons or higher and meter load 8.3 tons/m or higher.
- Train mass approximately 5200 tons on 10 ‰, 4200 tons on 12.5 ‰, or heavier.
- Maximum speed 250 km/h or higher for passenger trains
- Signalling system ERTMS level 2 in long term level 3.

Most of this performance has already been realised for the Öresund bridge from 2011 so to some extent the standard already exists. This will make the rail system considerably more competitive in the future also to fulfill the targets of EU for a sustainable transport system.

In the long term perspective building of dedicated high speed lines seems to be the right solution if the railway is to have a significant share of passenger transport as well as freight transport.
Figure: Proposed infrastructure improvements on Scandria core network.

Figure: Proposed High Speed Lines on Scandria core network.
1 Rail Corridors between Scandinavia and Northern Germany

1.1 Background

SCANDRIA – Scandinavian-Adriatic Corridor for Growth and Innovation – is a project in the Baltic Sea Programme for Corridor of Innovation and Cooperation (COINCO). The initiative comes from the regions of Gothenburg-Oslo, Øresund and Berlin-Brandenburg.

Scandria and COINCO-North are complementary projects with partial overlap of partners. In addition Scandria is supplemented by the SONORA, IBU-Öresund and STRING projects. Scandria also has a relation to other ongoing and proposed projects, such as the EWTC II, Trans-Baltic and Bothnian Green Logistic Corridor.

Scandria deals with the regions in the corridors between northern Germany to Denmark, Southern Sweden and continues in two corridors; one to Gothenburg and Oslo and one to Stockholm.

SONORA - South-North Axis - is directly connected with Scandria and is the southern part from northern Germany to the Adriatic Sea. Also here there are two corridors: one towards Switzerland and Italy to Rome and one towards the Adriatic Sea via Praha-Wien/Bratislava-Ljubljana in Croatia, see Figure 1.

The corridors covered in this report are the Scandria corridors from northern Germany to Denmark and southern Sweden and from there along the west coast to Gothenburg-Oslo and via Småland-Östergötland to Stockholm.

The Scandria project is in cooperation between partners from Germany, Sweden, Denmark, Norway and Finland. There are 19 different organisations represented, regional authorities as well as universities and institutes, ports and other organisations.

1.2 Aim and goals

The aim of the project is to increase the exchange of knowledge between the regions in the Scandria corridors and create prerequisites for a positive development of trade and transport between the regions. This must be in a long term sustainable way taken into account the climate crisis. This means that rail transport is essential. The transport corridors will be examined for all modes and improvements will be suggested for the future in scenario-analysis.

The first goal is to exchange knowledge on planning in the countries involved in the Scandria project and thus:

- Expand collaboration between universities in the corridor
- Expand exchanges of students
- Expand the collaboration between various practitioners/planning institutions within the corridor

The second goal is to define the market and the transport standard in the corridors.
First today’s transport will be analysed. Then the future development and the planned investments will be analysed. A gap analysis will be made to identify bottlenecks and weak links, and scenarios will be presented for future development.

**Figure 1.1. The Scandria and SONORA corridors.**

**Figure 1.2. The Scandria corridors covered in this report.**
1.3 Methods

This report covers:

- WP3: Quality of Transport Infrastructure, especially 3.2 Improvements in rail traffic
- WP5: Common Strategy of Corridor Functionality, especially 5.2 Benchmarking of the Corridor functionality.

The methods employed are:

- Investigation of rail infrastructure performance in the actual corridors. Suggestion of possible infrastructure parameters to be applied in the “functional corridors”.
- Analysis of rail freight production system for rail within the Scandria corridor in terms of wagonload and intermodal systems. Identifying big flows and rail competitiveness.
- Analysis of the rail passenger transport system. Identifying the biggest markets and the competitiveness of rail.
- Identification corridor functionality for freight and passenger transports. Identifying bottlenecks and weak links.
- Construction of scenarios for development of the rail transport systems including better service, upgraded or new infrastructure. Description of transport functionality and performance for corridor and connecting regions.
- A database for rail, road and air services in the Scandia-corridor has been worked together with WSP (as consultant to Region Skåne). The work with the database is almost completed and will be presented in a report with maps and tables which compares different modes and identifies bottlenecks.

The data which has been examined for the situation 2010 is shown in Table 1. By this database it is for example possible to make comparisons between the average speed between different city pairs by road, rail and air and via ferries or fixed links.

1.4 Delimitations

The corridors which are analysed are:

- From Stockholm, Hallsberg, Oslo, Malmö, Copenhagen in Scandinavia
- To Lübeck, Hamburg, Rostock and Berlin in Germany
- Via different ways by ferries or fixed links
- Also some domestic links in Germany are included i.e. Lübeck-Schwerin, Hamburg-Berlin and Rostock-Berlin

WSP is working with a summarised report for all modes from northern Germany to the southern Sweden. KTH is working with a special report about rail concentrated on long distance transport from northern Germany to Stockholm and Oslo which is presented in this report.
For rail (investigated by KTH)

- Rail infrastructure on the mainlines between the above-mentioned towns
  - Number of tracks
  - Maximum speed
  - Maximum axle load, meter load, loading gauge, train length and mass
  - Number of passenger and freight trains per day
  - Rail service for passenger traffic
  - Travel time (shortest and average)
  - Frequency (by different products)
  - Rail service for freight transport
  - Intermodal service (from Oslo and Stockholm via Malmö to Rostock, Travemünde and Hannover in Germany and Taulov in Denmark.
  - Wagonload service) from the marshalling yards in Hallsberg and Gothenburg in Sweden to Maschen and Seddin in Germany and Świnoujście in Poland

For air travel (investigated by KTH and WSP)

- Airplane service
- Travel time (between airports and from city to city)
- Frequency (between different airports)

For road transportation (investigated by WSP)

- Infrastructure (road standard)
- Travel time for passenger and freight movements

For ferry connections (investigated by WSP)

- Sailing time and total time including embarking
- Departures per week and company
- Available service (passengers, cars, trucks and rail wagons)

*Table 1.1. Database for road, rail, airplane and ferry connections*
2 Railway Infrastructure Performance

2.1 Measures for infrastructure standard

A transport corridor's infrastructure standards set physical limits for corridor capacity and transit times as well as train size and individual shipment size. The infrastructure standards will also influence transport costs and corridor fluidity and reliability.

Transit times, throughput capacity and reliability of each part of the corridor are limited by:

- number of tracks and sidings;
- maximum speed of each train and at each point;
- traffic management (signalling system) performance;
- traction power performance.

The size and capacity of individual trains is limited by:

- maximum gradients, given limitations in train tractive effort and braking performance;
- maximum train mass;
- maximum train length.

The size and capacity of individual wagons and shipments traversing a railway corridor is limited by:

- maximum meter load, i.e. load per meter of track;
- maximum axle load, i.e. load per axle;
- loading gauge, i.e. cross section dimensions.

Thus the infrastructure standards are of interest to the passenger, shipper, train operator and corridor manager alike, and will influence each corridor’s overall competitiveness vs. other transport modes and other corridors.

Note that the capacity of nodes, i.e. junctions, yards and stations, is as important as the capacity of the connecting links. To achieve the best overall system performance and efficiency, any weak parts must be identified and strengthened or eliminated.

The above parameters are being charted for the railway corridors concerned. The limits mentioned below are those that are prevalent on main lines or applicable in the Scandria corridor. Exceptions outside the Scandria corridor may exist.

An overview of the rail infrastructure is given in Figure 2.1.
Figure 2.1. The rail infrastructure core network of the Scandria corridors described in this report.
The most important factors of the infrastructure which affect the capacity and efficiency of rail freight transports have been investigated and maps have been developed to get an overview of the performance. This has also been used to identify the weakest links in order to make suggestions for future common standards in the Scandria corridor at the end of this report.

The following parameters are investigated and mapped:

- Number of tracks
- Maximum speed
- Power supply
- Traffic control system
- Gradient southbound/northbound
- Axle load
- Meter load
- Loading gauge, general
- Loading gauge, intermodal
- Intermodal terminals and rail ferry ports
- Train length
- Siding lengths on single track lines
- Train mass
- Ferry lines

The main sources used are network statements of the infrastructure managers supplemented by own investigations. Not all parameters are published or presented in a consistent way, so significant work has been done to get complete maps for the core network.
2.2 Number of tracks

Double track enables trains to meet without stopping. This significantly increases corridor capacity in number of train paths per day, reduces transit times, and makes traffic less sensitive to disturbances compared to single track. Where traffic is mixed with different speeds, quadruple track is desirable, enabling trains both to meet and to pass.

The present situation with single and double track sections is shown in Figure 2.2.

The Scandria corridor south of Stockholm and Oslo is largely double track, except for the following single track sections, shown with total length and in parentheses the longest distance between passing sidings:

- **Norway:** Sandbakta-Såstad (Rygge) 10 km (4 km), Haug-Kornsjø 95 km (9 km)
- **Sweden:** Kornsjö-Öxnered 98 km (26 km), Velanda-Flunbo 13 km (8 km), Bohus-Marieholm 13 km (7 km), Varberg-Hamra 7 km, Båstad Norra-Verbysslätt 18 km (9 km), Ängelholm-Helsingborg 26 km (7 km), Ängelholm-Arlöv 74 km (25 km), Hallsberg-Degerön 48 km (11 km), Motala-Fälgesta 9 km, Järna-Åby 108 km (14 km), Lockarp-Trelleborg 24 km (7 km)
- **Öresund link:** no single track section
- **Denmark:** Vamdrup-Vejens 18 km (6 km), Tinglev-Padborg 12 km (6 km), Vordingborg-Redby 63 km (7 km)
- **Germany:** Puttgarden-Bad Schwartau 82 km (7 km)

Short quadruple track sections exist near Stockholm, Malmö, Roskilde, Hamburg and Berlin.

A short quadruple track near Oslo is also planned, as well as a new double track København-Køge-Ringsted.

When track duplications that are currently in the respective national plans have been completed, the following sections will still remain single track, with total length and in parentheses the longest distance between sidings:

- **Norway (2017 estimated):** Haug-Kornsjø 95 km (9 km)
- **Sweden (2021 estimated):** Kornsjö-Öxnered 98 km (26 km), Maria-Helsingborg 5 km, Ängelholm-Arlöv 74 km (25 km), Järna-Åby 108 km (14 km), Lockarp-Trelleborg 24 km (7 km)
- **Öresund connection:** no single track section
- **Denmark (2018):** Tinglev-Padborg 12 km (6 km), Storstrøm bridge 4 km, Køge-Næstved 37 km (9 km)
- **Germany (2025):** Fehmarnsund bridge 1 km

Of the remaining single track sections per above, traffic on Ängelholm-Arlöv will increase significantly when the Hallandsås tunnel north of Ängelholm is opened, planned for 2015. As currently configured, Ängelholm-Arlöv looks set to become a bottleneck due to its few sidings with long distances up to 25 km in between, severely limiting its throughput capacity.
Traffic increases between Oslo and Gothenburg may also be hampered due to remaining single track with up to 26 km between sidings.

Figure 2.2. Number of tracks on the Scandria core network (Between Gothenburg and Öxnered the sections Velanda-Flunbo and Bohus-Marieholm will be opened in December 2012).
2.3 Maximum speed

High sustained speeds over long distances result in short transit times, but large differences in speed between trains on the same track reduce capacity and necessitate passings.

The prevalent maximum speeds in the Scandria corridor are as follows:

- Finland: 200 km/h; freight 100 km/h and 120 km/h
- Norway: Oslo-Kornsjo 130 km/h to 160 km/h; freight 80 km/h to 100 km/h
- Sweden: Kornsjo-Skælebol-Öxnered 160 km/h, Öxnered-Gothenburg-Malmö 200 km/h, Hallsberg-Mjölby 130 km/h to 160 km/h, Stockholm-Katrineholm-Malmö 200 km/h, Järna-Åby 160 km/h, Ängelholm-Arlöv 140 km/h, Malmö-Trelleborg 110 km/h; mail 160 km/h; freight 100 km/h
- Öresund link: Denmark 180 km/h, Sweden 200 km/h
- Denmark: København-Ringsted 180 km/h, Ringsted-Vordingborg 140 km/h, Vordingborg-Rødby 120 km/h to 140 km/h, Køge-Næstved 120 km/h, Ringsted- Padborg 160 km/h to 180 km/h; freight 100 km/h
- Germany: Flensburg-Hamburg 160 km/h, Puttgarden-Bad Schwartau 100 km/h to 160 km/h, Bad Schwartau-Hamburg 160 km/h, Rostock-Berlin 120 km/h to 160 km/h, Sassnitz-Berlin 120 km/h; freight 100 km/h
Figure 2.3. Maximum line speeds on the Scandria core network.
2.4 Power supply

Electrification has the ability to supply high traction power and short-time overloads, thereby enabling high speeds, heavy trains and high acceleration if dimensioned for sufficient power capacity. All main lines in the Scandria corridor are electrified, except:

- Denmark: Ringsted-Rødby 119 km, Køge-Næstved 39 km
- Germany: Puttgarden-Bad Schwartau 82 km

As links to the fixed Fehmarnbelt connection, Ringsted-Rødby and Puttgarden-Bad Schwartau are to be electrified by 2021. The power demands on new and existing lines depend on traffic intensity, but are beyond the scope of this report.

*Figure 2.4 Power supply system on the Scandria core network.*
2.5 Traffic control system

The traffic control systems are shown in figure 2.5. Sweden and Norway have the same system ATC (Automatic Train Control) except for links Storlien-Vaernes in Norway and Ställdalen-Kil in Sweden. Finland has another ATC-system (ATC-JKV) and Denmark has a third system (ATC-KVB 450). The fourth ATC-system is in Germany and is called Indusi. That’s why the signaling systems are going to be standardized and replaced by the European signaling system ETCS (European Traffic Control System). So far ERTMS has been introduced only on one line in Sweden, the new built Bothnia link between Umeå and Kramfors (Västeraspby) and the rebuilt Ådalsbanan between Härnösand and Kramfors.

Figure 2.5 Traffic control system on the Scandria core network.
2.6 Gradient

Low gradients benefit mainly slow and heavy trains, whose low speed gives less momentum to climb a hill. A train must also be able to start again if stopped at any point. Given limitations in power supply performance and tractive effort, as well as varying weather conditions, a high gradient will restrict the practical train mass that can be handled reliably. High gradients should therefore be avoided.

The prevalent maximum gradients applied in the Scandria corridor and exceptions are as follows:

- Norway: 12 ‰ Oslo-Kornsjø but 23 ‰ southbound Halden-Aspedammen and 25 ‰ northbound Oslo-Bryn (near Alnabru)
- Sweden: 10 ‰ Kornsjø-Malmö but 12.5 ‰ at Ängelholm and 25 ‰ at Landskrona (passenger trains only); 10 ‰ Hallsberg-Malmö but 11.5 ‰ at Boxholm; 10 ‰ Stockholm-Mjölby but 13.4 ‰ at Katrineholm; 10 ‰ Järna-Åby but 10.5 ‰ at Vagnhärad; 10 ‰ Malmö-Trelleborg
- Öresund connection: 15.6 ‰ at Peberholm
- Denmark: 16.5 ‰ at Storebælt (east tunnel)
- Germany: 12 ‰ at Rendsburg

Constraints are the grades at Oslo, Halden and the Öresund and Storebælt connections. The grade at Landskrona is not a real constraint to freight, as the parallel route Ängelholm-Arlöv is both flatter and shorter.
Figure 2.6 A Southbound gradients on South Bound track on the Scandria core network.
Figure 2.6B Northbound gradients on North Bound track on the Scandria core network.
2.7 Axle load

A high axle load limit is beneficial to almost all commodities, with the number of axles per car/wagon depending on the density of the commodity.

The maximum static axle load is set depending on the rail material and cross section, the rail fastener, the crosstie type and spacing and the ballast depth to avoid damage to these components and substructure, leaving a margin for dynamic load peaks at speed. Overloads, which exceed the maximum static axle load, may or may not be permissible on a particular line or only under special conditions such as reduced speed.

The prevalent axle load limits applied in Scandinavia and Germany are as follows (metric tons):

- Finland: 22.5 tons, 25 tons
- Norway: 22.5 tons, 25 tons, 30 tons Riksgränsen-Narvik
- Sweden: 22.5 tons, 25 tons, 30 tons on designated lines
- Öresund connection: 22.5 tons
- Denmark: 22.5 tons
- Germany: 22.5 tons, 25 tons on designated lines
- Poland: 22.5 tons

A weak link is the Rendsburg bridge in Germany, which is classified for 20 tons axle load, but is being strengthened to allow 22.5 tons, to be completed in 2014.\(^3\)

25 tons is the normal axle load limit on newly built or upgraded lines in Sweden, and Norway is upgrading the Scandria corridor (Østfoldbanen) and several adjacent lines to this axle load.\(^2\) In Finland this is the limit of several main lines in the south, and all new wagons are built for 25 tons axle load. Germany so far has one corridor (Hamburg – Salzgitter) for 25 tons axle load, and is currently upgrading a second corridor (Rostock – Berlin) to this limit, to be opened in 2015.\(^4\) (A third exists in the Saar.)

30 tons is the axle load limit on the iron ore line in Sweden and Norway, and is also the design load for the foundation of new or upgraded lines in Sweden. In addition to ore wagons, some recent wagons for steel, logs, pulpwood and paper are also built for 30 tons axle load.
Figure 2.7 Axle loads on the Scandria core network
2.8 Meter load

A high meter load limit is useful for high density commodities, enabling a high payload within a limited track length, thus reducing either the number of trains needed or the length of yard tracks and sidings needed. Steel slabs and coils are examples of commodities benefiting from a high meter load. Large numbers of wagons used to haul steel sheet coils reach 8.3 tons/m when loaded to their axle load limit of 25 tons.

The maximum load per meter of track is set depending on the strength of the track foundation including bridges. Overloads for an individual car/wagon may be acceptable if sandwiched between empty wagons/cars.

The prevalent meter load limits applied in Scandinavia and Germany are as follows (metric tons per meter):

- Finland: 8 tons/m
- Norway: 6.6 tons/m, 8.3 tons/m Kornsjø-Oslo, 12 tons/m Riksgränsen-Narvik
- Sweden: 6.4 tons/m, 8 tons/m, 12 tons/m on designated lines
- Öresund connection: 8.3 tons/m
- Denmark: 7.2 tons/m, 8 tons/m
- Germany: 6.4 tons on the Rendsburg bridge, 8 tons/m

8 tons per meter is the normal meter load limit on main lines in Germany, Denmark and Finland. The Rendsburg bridge in Germany is classified as 6.4 ton/m, but is being strengthened to 8 tons/m for simultaneous use of one track only, to be completed in 2014.¹

Weak links remain the 6.4 and 6.6 tons/m that are prevalent in southern Sweden and Norway, respectively. As lines in Sweden are upgraded to 25 tons axle load and loading gauge C, the meter load is normally upgraded to 8 tons/m at the same time. Upgrading to 25 tons axle load in combination with 8.3 tons/m would be desirable, to be able to use the full capacity of the current wagons for steel sheet coils.
Figure 2.8A Meter loads on the Scandria core network
2.9 **General loading gauge**

A generous loading gauge is important for large items such as containers and trailers, but also for low- to-medium density commodities which would otherwise “cube out”, i.e. reach volume limits before reaching weight limits.

The loading gauge defines the maximum cross section of railway cars/wagons and their lading for which a particular line is cleared, leaving a margin for dynamic motions to avoid fouling of lineside structures or adjacent tracks. Oversize shipments, which exceed the loading gauge, will require checking of trackside clearances and may or may not be permissible on a particular line or only under special conditions such as reduced speed.

The prevalent loading gauges applied in Scandinavia and Germany and their maximum dimensions (height × width) are as follows:

- Finland: KU (5.3 m × 3.4 m)
- Norway: M (4.595 m × 2.86 m), N (4.35 m × 3.4 m), U (4.45 m × 3.4 m)
- Sweden: A (4.65 m × 3.4 m), C (4.83 m × 3.6 m)
- Öresund link: UIC GC (4.65 m × 3.15 m)
- Denmark: G2 (4.65 m × 3.15 m)
- Germany: G2 (4.65 m × 3.15 m)
- Poland: G2 (4.65 m × 3.15 m)

The most generous of these are the Finnish KU and the Swedish C loading gauges. Almost the entire Finnish network is cleared for KU loading gauge, while Swedish lines cleared for loading gauge C presently reach from Halmstad to Boden, with additional lines being cleared successively. Commodities already benefiting from loading gauge C include trailers, containers, paper, lumber, logs and pulpwood. (Exceeding loading gauge C, wagons up to 3.77 m wide are used in northern Sweden to haul lumber.)

A particular problem of many loading gauges is their narrow width at the top, which not only restricts the size of containers and trailers that can be carried, but also restricts rational wagon construction for other loads of rectangular cross section. To compare the utility of the prevalent loading gauges, the rectangular cross section area above floor level (1.2 m height) is plotted in figure 2.9A.
Figure 2.9A Inscribed rectangular cross section above floor level (1.2 m ATOR) or container mounts (1.175 m ATOR)

Figure 2.9B. Loading gauges and intermodal gauges of Germany, Denmark, Øresund, Sweden, Norway and Finland
Figure 2.9 General loading gauges on the Scandria core network
Figure 2.10 Intermodal loading gauges on Scandria core network. At Southern Mainline between Södertälje and Hässleholm P/C 450 is restricted to single track use at 4 short distance.
### 2.10 Intermodal loading gauge

For intermodal units such as semitrailers, the intermodal gauge defines the maximum height in cm of a 2.60 m wide trailer, measured from the 0.33 m floor height of a UIC standard pocket wagon [30]. The mainlines connecting Scandinavia and Germany accommodate the loading gauges and intermodal gauges shown below:

- Finland: KU and P/C 497 (420 cm lorries on 1.1 m flat wagons);
- Norway: Oslo-Kornsjø M, U and P/C 410;
- Øresund: UIC GC and P/C 450;
- Denmark: Øresund-Kolding-Padborg G2 and P/C 410, Ringsted-Rødby G2 and P/C 400, Køge-Næstved G2, København-Køge-Ringsted not announced;
- Germany: G2 and P/C 410, but P/C 405 at Bad Oldesloe.

The loading gauges and their main dimensions are shown in Figure 2.9A and Table 2.9B.

**Table 2.10B: Dimensions of the largest loading gauges and intermodal gauges [16], [30], [31], [32], [33], [34].**

<table>
<thead>
<tr>
<th></th>
<th>Germany, Denmark</th>
<th>Øresund</th>
<th>Sweden</th>
<th>Norway</th>
<th>Finland</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Loading gauge</strong></td>
<td>G2</td>
<td>UIC GC</td>
<td>C</td>
<td>M, U</td>
<td>KU</td>
</tr>
<tr>
<td>Height (m)</td>
<td>4.65</td>
<td>4.65</td>
<td>4.83</td>
<td>4.595</td>
<td>5.30</td>
</tr>
<tr>
<td>Width (m)</td>
<td>3.15</td>
<td>3.15</td>
<td>3.60</td>
<td>3.40</td>
<td>3.40</td>
</tr>
<tr>
<td><strong>Intermodal gauge</strong></td>
<td>P/C 410</td>
<td>P/C 450</td>
<td>P/C 450</td>
<td>P/C 410</td>
<td>P/C 497</td>
</tr>
<tr>
<td>Height (m)</td>
<td>0.33+4.10</td>
<td>0.33+4.50</td>
<td>0.33+4.50</td>
<td>0.33+4.10</td>
<td>1.10+4.20</td>
</tr>
<tr>
<td>Width (m)</td>
<td>2.60</td>
<td>2.60</td>
<td>2.60</td>
<td>2.60</td>
<td>2.60</td>
</tr>
</tbody>
</table>

The tall P/C 450 intermodal gauge, which applies on the Øresund link as well as lines with loading gauge C in Sweden, enables the following load combinations:

- Lift-on lift-off loading of 4.50 m high semitrailers onto UIC standard pocket wagons;
- Roll-on roll-off loading of 4.00 m high semitrailers onto flat wagons with 0.83 m floor height;
- Standard 1.10 m high lumber packages stacked three high onto standard flat wagons;
- 3.56 m (140") high paper rolls loaded under sliding hoods in a possible new wagon design.

### 2.11 Train length

Extending the length of trains effectively raises the payload per train, regardless of the commodities carried. Longer trains also make it possible to more fully utilise the high power ratings of modern locomotives. This is particularly important for trains with low meter load, such as intermodal trains.
Since a large portion of the operating cost per train is fixed, notably the cost of locomotive and crew, operating larger trains where there is high demand for transport can reduce the cost per load unit, to the potential benefit of both operator and shippers.

In contrast to the line improvements necessary for higher axle loads and meter loads, extended train length can be accomplished with point improvements such as constructing longer yard tracks and sidings.

Braking performance also limits the acceptable length of trains with air brakes.

With respect to braking performance the maximum train lengths acceptable in Scandinavia and Germany are as follows:

- Finland: 925 m with G brake and direct-release control valves, 825 m with G brakes and graduated release control valves, 725 m with P brake
- Norway: 850 m with G brake up to 80 km/h, 700 m with P brake up to 80 km/h, 600 m up to 90 km/h, 500 m up to 100 km/h
- Sweden: 880 m with G brake up to 80 km/h, 730 m with P brake
- Öresund connection: 1000 m
- Denmark: 835 m up to 120 km/h, 600 m up to 100 km/h
- Germany: 835 m Maschen-Padborg, 740 m elsewhere

Practical train length is also limited by the length of yard tracks and sidings, specific for each line and yard. In the short term, longer trains may be the least capital intense way to effectively raise corridor capacity.
Figure 2.11B Long tracks of freight yards of the Scandria core network.
Figure 2.11C Lengths of passing sidings on single track sections of the Scandria core network.
2.12 Train mass

Increased train lengths and higher meter loads make it possible to increase the payload per train.

Train mass limits currently in effect are:

- Öresund link: 4000 tons;
- Denmark: 2500 tons between Copenhagen and Padborg;
- Germany: 4000 tons with screw couplers.

In contrast, Sweden has no absolute limit in effect, but rather individual ratings for each line and each locomotive type. Whereas the rating per locomotive is set to avoid stalling and to ensure a certain balanced speed, depending on local gradients and curvature, the ratings for double locomotives operating in tandem are in many cases restricted by the power supply and distribution performance. Trains of 3200 tons are operated regularly on lines with up to 17 ‰ gradient, using double four-axle locomotives on the head end, each rated at 1600 tons trailing tonnage.

In Denmark, modern four-axle locomotives are rated at 1600 tons to 1700 tons trailing tonnage across Store Bælt due to the combination of grades and curves present there. Thus, the absolute train mass limit of 2500 tons on this route is more restrictive than the physical capability of two locomotives.

For comparison, modern sliding-door wagons, as are used for paper products, if loaded to 22.5 tons axle load weigh approximately 3.8 tons/m, totalling approximately 3000 tons for a 790-meter long rake of wagons. Wagons for steel sheet coils, if loaded to 22.5 tons axle load weigh approximately 7.5 tons/m, totalling approximately 5900 tons for a 792-meter rake of wagons. Thus, the present absolute mass limit of 2500 tons is what limits train payload capacity through Denmark.
2.13 Rail ferry links

There are as of 2012 four rail ferry connections between Sweden and northern Europe:

- Gothenburg – Fredrikshavn, railway wagons not handled regularly
- Trelleborg – Rostock, three ferry departures per day in each direction
- Trelleborg – Sassnitz, four ferry departures per day in each direction
- Ystad – Świnoujście, two departures per day in each direction

The four train ferries used on the Trelleborg – Rostock and Trelleborg – Sassnitz routes have the following capabilities according to Scandlines:

- Total track length 711 m, 755 m, 928 m and 1131 m
- Axle load 22 tons (m/s Trelleborg) and 25 tons
- Meter load 8 tons/m for structural purposes, but not the whole ferry deck can be filled at this load
- Free height 4.80 m and 4.85 m.

The capacity of the ferry lines in track length compared with the maximum train lengths is shown in figure 2.13.

The axle load capability of the train ferries exceeds the present 20-ton limit of the Rendsburg bridge between Padborg and Hamburg. Thus, wagons loaded to 22.5 tons axle load cannot be routed through Rendsburg and onward through Denmark until strengthening of the Rendsburg bridge is complete in 2014, but can be shipped by ferry via Trelleborg.

A new possibility of 25 ton high axle loads will open in 2015, as the strengthened railway line Rostock – Berlin – Zilitendorf is to be opened.

![Train length (m)](chart)

Figure 2.12 Track lengths on ferry lines and permitted train length with different break-systems.
3 Rail Freight Performance

3.1 Key routes for wagonload and unit trains

Rail freight corridors are different from rail passenger corridors. Whereas rail passenger corridors connect the big metropolitan areas and mainly by ferry-link Rødby-Puttgarden, rail freight corridors go from big marshalling yards and terminals, situated outside the big towns near population or industrial concentrations or at the intersection between major flows.

In Sweden the biggest nodes for wagonload freight are Hallsberg, where freight from northern Sweden is re-classified, and Malmö, where freight to Europe is assembled to trains. Also in Gothenburg (Gothenburg) there is a big marshalling yard which handles hinterland container traffic from the Gothenburg seaport. International wagonload service to Norway is increasing, and is handled mainly by the Drammen freight yard.

Rail freight uses not only the fixed link across Öresund and Great Belt via Padborg to Germany but also to a lesser extent the ferry links to Sassnitz, Rostock and Świnoujście. The Rødby-Puttgarden ferry link is no longer used for freight.

Wagonload traffic goes mainly via the hubs of Hallsberg or Malmö in Sweden and Maschen in Germany. The main route for this traffic is through Denmark via Padborg. The main route is relieved by train ferries Trelleborg-Rostock and Trelleborg-Sassnitz to Maschen, handling daily wagonload trains between Borlänge and Seddin and between Malmö and Seddin, and less frequent wagonload trains between Maschen and Malmö, Trelleborg and Verona/Trevisio, Trelleborg and Domodossola.

Wagonload traffic to Central or Eastern Europe is also handled via Ystad – Świnoujście, including direct trains between Ystad and Vienna (Wien).

Major unit train flows between Scandinavia and Germany and beyond serve in particular the paper and automobile industries. These include approximately 30 unit trains of paper products re-assembled in Malmö and operated as unit trains to Maschen and Dortmund, about 12 trains per week in each direction operated as unit trains between Ålmhult and Gent with auto parts, and daily intermodal trains between Gothenburg and Hannover, also carrying auto parts.

The designated freight capacity of each route is as follows, in each direction:

- land route via Padborg, 48 freight train paths per day in each direction
- rail ferry link via Trelleborg – Rostock, three ferry departures per day in each direction
- rail ferry link via Trelleborg – Sassnitz, four ferry departures per day in each direction.

From 2021 the new fixed link via Rødby – Puttgarden (Fehmarnbelt) will be available. This new fixed link will reduce the distance between København and Hamburg by about 160 km compared to the existing route via Padborg, and will also have capacity for 48 freight trains per day in each direction.
Figure 3.1: Rail Freight Corridors.
Table 3.1 Direct rail freight relations for wagonload, unit trains and intermodal trains 2011

### Wagonload trains

<table>
<thead>
<tr>
<th>Route</th>
<th>Frequency</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borlänge–TS–Seddin o/w</td>
<td>6/wk</td>
<td>Green Cargo</td>
</tr>
<tr>
<td>Malmö–ØSB–Fredericia r/t</td>
<td>5/wk</td>
<td>Green Cargo</td>
</tr>
<tr>
<td>Malmö–ØSB–Maschen r/t</td>
<td>27/wk</td>
<td>Green Cargo</td>
</tr>
<tr>
<td>Malmö–TS–Seddin o/w</td>
<td>5/wk</td>
<td>Green Cargo</td>
</tr>
<tr>
<td>Trelleborg–TR–Domodossola r/t</td>
<td>1/wk</td>
<td>Nordisk Transport Rail</td>
</tr>
<tr>
<td>Trelleborg–TR–Treviso r/t</td>
<td>2/wk</td>
<td>Nordisk Transport Rail</td>
</tr>
<tr>
<td>Maschen–ST–Malmö o/w</td>
<td>3/wk</td>
<td>Green Cargo</td>
</tr>
<tr>
<td>Seddin–ST–Malmö o/w</td>
<td>12/wk</td>
<td>Green Cargo</td>
</tr>
</tbody>
</table>

### Unit trains

<table>
<thead>
<tr>
<th>Route</th>
<th>Frequency</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Älmhult–ØSB–Gent Z r/t</td>
<td>12/wk</td>
<td>Volvo</td>
</tr>
<tr>
<td>Gothenburg A–ØSB–Hannover Lin. r/t</td>
<td>5/wk</td>
<td>Volvo</td>
</tr>
<tr>
<td>Malmö–ØSB–Maschen r/t</td>
<td>12/wk</td>
<td>Scandfibre Logistics</td>
</tr>
<tr>
<td>Malmö–ØSB–Dortmund O/S r/t</td>
<td>19/wk</td>
<td>Scandfibre Logistics</td>
</tr>
</tbody>
</table>

### Intermodal trains

<table>
<thead>
<tr>
<th>Route</th>
<th>Frequency</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oslo A–Malmö–Trelleborg r/t</td>
<td>6/wk</td>
<td>CargoNet</td>
</tr>
<tr>
<td>Oslo A–ØSB–Rotterdam RSC r/t</td>
<td>2/wk</td>
<td>Bring Frigo</td>
</tr>
<tr>
<td>Katrineholm–ØSB–Herne WW r/t</td>
<td>5/wk</td>
<td>van Dieren Maritime</td>
</tr>
<tr>
<td>Nässjö–ØSB–Herne WW r/t</td>
<td>3/wk</td>
<td>van Dieren Maritime</td>
</tr>
<tr>
<td>Gothenburg G–ØSB–Herne WW r/t</td>
<td>5/wk</td>
<td>van Dieren Maritime</td>
</tr>
<tr>
<td>Helsingborg–ØSB–Herne WW r/t</td>
<td>4/wk</td>
<td>van Dieren Maritime/KV</td>
</tr>
<tr>
<td>Malmö–ØSB–Taulov r/t</td>
<td>7/wk</td>
<td>Hupac</td>
</tr>
<tr>
<td>Malmö–ØSB–Herne WW r/t</td>
<td>6/wk</td>
<td>TX Logistik</td>
</tr>
<tr>
<td>Taulov–Hamburg Billwerder r/t</td>
<td>3/wk</td>
<td>Kombiverkehr</td>
</tr>
<tr>
<td>Taulov–Busto Arsizio G r/t</td>
<td>10/wk</td>
<td>Hupac</td>
</tr>
<tr>
<td>Taulov–Verona QE r/t</td>
<td>5/wk</td>
<td>Hupac</td>
</tr>
<tr>
<td>Padborg–Hall–Verona QE r/t</td>
<td>2/wk</td>
<td>TX Logistik</td>
</tr>
<tr>
<td>Padborg–Verona QE r/t (direct)</td>
<td>2/wk</td>
<td>TX Logistik</td>
</tr>
</tbody>
</table>
Intermodal transportation connects various hubs, depending on the operator.

Traffic from Norway:
- Cargo Net between Alnabru – Malmö – Taulov and onward to Europe.
- TX Logistik between Alnabru – Malmö – Duisburg and onward.

Traffic from Sweden:
- Cargo Net Malmö – Taulov and onward
- DB Cargo Hallsberg – Maschen (wagonload system)
- TX Logistik Malmö – Duisburg
- Van Dieren Maritime Katrineholm – Herne, Nässjö – Herne, Gothenburg – Herne and Helsingborg – Herne

Much of the intermodal transportation runs via the ports of Malmö, Trelleborg and Ystad in a domestic system and onward by ferry via Travemünde/Lübeck, Sassnitz, Rostock and Świnoujście.

Existing and planned intermodal terminals are shown in Figure 3.2.
Figure 3.2 Inter modal terminals in the Scandria region
3.2 Transport flows

Substantial amounts of freight are transported from northern and central Sweden that then continues south to Skåne for export. Considerable amounts of freight are also transported between Skåne and Mälardalen and places in-between. Between Stockholm/Mälardalen and the Bergslagen district and Gothenburg there is considerable freight traffic to places such as the Port of Gothenburg and to industries in the west of Sweden.

An overview of the freight volumes on the railways from Hallsberg to region Skåne and south, to Gothenburg and along the west coast is shown by Figure 3.3. The largest flow is from Hallsberg to Mjölby and then on the southern main line to Denmark and the continent. The total volume is about 8 millions of tonnes per year of which about 6 millions of tonnes are international transports. The international transports will continue on the Öresund bridge or via rail ferries to the continent.

The volume from Hallsberg to Gothenburg is about 5 millions of tonnes per year and is to a large extent bound for the port of Gothenburg for international shipping. From Gothenburg and southwards on the West Coast Main Line are about 2 millions of tonnes transported of which about 1 million tons is bound for Denmark and the continent.
Figure 3.3 Freight flows by rail 2006.
3.3 Rail competitiveness

The railways' market share of international freight traffic is only half the market share they have of domestic traffic in Sweden, despite long distances and large volumes. This is a result of insufficient investment and the fact that deregulation has not yet been fully implemented for the railways in all countries while truck traffic is fully deregulated. In Sweden a deregulated railway market has been functioning for a few years now, and this has meant more operators and improved quality and freedom of choice for customers. An example of this is the rapid expansion of intermodal traffic to the Port of Gothenburg and the fact that an increasing share of the freight is being transported by rail.

The amount of freight transported by road on international routes is enormous – 37 million tons in 2006. If this development continues road transportation will overtake shipping, which transported 41 million tons (not including ore and oil), while only 7 million tons were transported by rail. 37 million tons is equivalent to 10,000 trucks a day. About half of this number, or 5,500 trucks, travel south towards Denmark and the European continent. This is equivalent to more than 200 trucks per hour or one truck every 15 seconds.

Long-distance truck traffic is a dominant feature on south-bound routes to the continent and Gothenburg. One example is that where the E6 and E4 European highways converge just north of Helsingborg, the total traffic load was 29,000 vehicles per day of which 23% were heavy vehicles. Heavy traffic accounted for approximately 77% of the load on the roads measured in gross ton kilometres. Weight is a greater factor as regards wear to the roads than the number of vehicles. The risk of accidents and the consequences of accidents also increase as the proportion of heavy traffic increases.

International truck traffic accounted for approximately 70% of the heavy traffic. International traffic thus has a very great bearing on the load on the road network and accordingly also on maintenance costs and accident risk. If traffic continues to increase at the same rate as previously and truck traffic accounts for the whole increase in international traffic, it will increase by 44% between 2006 and 2020. The increase alone is equivalent to 2,500 trucks per day on the roads to the continent.

International rail traffic, meanwhile, is in the process of reversing a trend. The private railway company Hector Rail and also Green Cargo have bought new multi-system locos and are beginning to operate direct trains between Sweden and the continent. The railways’ market share in Germany is also increasing for the first time in a long time, both in domestic and international traffic.

If the railways are allowed to compete by fully implementing deregulation and making sufficient capacity available, they would be able to swallow the whole increase. Forecasts show that if the railways can offer sufficient quality and capacity, 2,500 trucks could be replaced by 60 freight trains every day. For this to work, the capacity available to freight trains must also be increased on the main lines.

It can be noted that the railway's market share varies considerably to different countries. It is highest in western Europe with 15% and to those countries in eastern Europe that have standard gauge with 13%. Norway is next with 10% while Denmark has only 4% market share. Great Britain and Spain-Portugal along with some southern European countries (Greece, Turkey, etc) and countries in eastern Europe with broad-gauge railways have a market share of 0%. In some cases, however, intermodal transportation or transportation where freight is trans-shipped at borders may exist.

Interoperability naturally plays a part, but the degree of deregulation and market orientation on the part of the railway companies concerned is also of great importance. Despite the difference in gauges, the
market share to Finland is 7% while it is only 4% to Denmark, which has the same gauge. Most traffic to Finland goes by ferry and the wagons are fitted with a bogie exchange system. However, the ferry connection from Stockholm to Turku was discontinued in 2012. The Öresund Bridge had a short term effect that it is more difficult to run trains to Denmark since the ferries no longer operate and multisystem locomotives are needed to haul trains over the bridge. But since Railion, Green Cargo and Hector Rail have obtained multi-systems locomotives the traffic has increased.

The technical solutions to overcome the difficulties of different gauges and current types exist; it is rather the organisational prerequisites that are not yet sufficiently developed. Deregulation has hitherto primarily given results in domestic traffic. In order for it to also have an effect on international traffic, it must be fully implemented in all countries in Europe. Several decisions have been taken by the EU in order to achieve a functioning railway market and development is also under way.
Table 3.1 International transports to and from Sweden 2006.

<table>
<thead>
<tr>
<th>Freight volume between Sweden and Europe excl. ore and oil</th>
<th>Volume 2006</th>
<th>Marketshare %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Milj. Ton</td>
<td>Share %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rail</td>
</tr>
<tr>
<td><strong>Millions of tonnes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>9.0</td>
<td>11%</td>
</tr>
<tr>
<td>Norway</td>
<td>11.6</td>
<td>14%</td>
</tr>
<tr>
<td>Denmark</td>
<td>8.1</td>
<td>9%</td>
</tr>
<tr>
<td>Western Europe excl UK</td>
<td>31.3</td>
<td>37%</td>
</tr>
<tr>
<td>Eastern Europe standard gauge</td>
<td>4.4</td>
<td>5%</td>
</tr>
<tr>
<td>Eastern Europe broad gauge</td>
<td>9.6</td>
<td>11%</td>
</tr>
<tr>
<td>Spanien-Portugal</td>
<td>2.8</td>
<td>3%</td>
</tr>
<tr>
<td>Storbritannien</td>
<td>6.5</td>
<td>8%</td>
</tr>
<tr>
<td>Other Europe</td>
<td>2.0</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td>85.4</td>
<td>100%</td>
</tr>
<tr>
<td>of which</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to European continent</td>
<td>46.6</td>
<td>55%</td>
</tr>
<tr>
<td>to other countries</td>
<td>38.8</td>
<td>45%</td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td>85.4</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 3.2 International transports to and from Sweden 2006.

<table>
<thead>
<tr>
<th>Freight volume between Sweden and Europe excl. ore and oil 250 days per year</th>
<th>By rail</th>
<th>By truck</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume</td>
<td>Number of</td>
</tr>
<tr>
<td></td>
<td>ton</td>
<td>freight trains</td>
</tr>
<tr>
<td></td>
<td>Millions</td>
<td>per day</td>
</tr>
<tr>
<td>Finland</td>
<td>0.6</td>
<td>4</td>
</tr>
<tr>
<td>Norway</td>
<td>1.2</td>
<td>8</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.3</td>
<td>2</td>
</tr>
<tr>
<td>Western Europe excl UK</td>
<td>4.6</td>
<td>30</td>
</tr>
<tr>
<td>Eastern Europe standard gauge</td>
<td>0.6</td>
<td>4</td>
</tr>
<tr>
<td>Eastern Europe broad gauge</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Spanien-Portugal</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Storbritannien</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Other Europe</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td>7.3</td>
<td>49</td>
</tr>
<tr>
<td>of which</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to European continent</td>
<td>5.5</td>
<td>36</td>
</tr>
<tr>
<td>to other countries</td>
<td>1.8</td>
<td>12</td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td>7.3</td>
<td>49</td>
</tr>
</tbody>
</table>
Figure 3.4 Transports between Sweden and Denmark and the western European continent 2006. Includes transports in both directions. Prerequisites: EU-trucks with average load 15 tonnes, freight train with average load 600 tonnes, one freight train=40 trucks.

Figure 3.5 Development of international transportation by rail and truck between 1970 and 2006 and development with and without capacity and deregulation until 2020.
4 Rail Passenger Transport Performance

4.1 Key routes for passenger transport

Rail passenger corridors go from the big towns to the big towns: Stockholm, Oslo, Gothenburg to Malmö and via the Öresund bridge to Copenhagen. From Copenhagen the trains mainly go by ferry-link Rødby-Puttgarden to Hamburg and then to Berlin. There are also night trains via Padborg and Trelleborg-Sassnitz but not daily.

The long distance lines in the corridors by different products are shown by figure 4.2. In the corridor from Stockholm to Berlin there are direct high speed trains from Stockholm to Copenhagen with SJ X2000. There are 6 departures in each direction directly to Copenhagen and 5 more departures to Malmö with possibility to change to Regional Öresund trains from Malmö to Copenhagen. From Copenhagen there are direct highs speed trains to Hamburg with DB ICE trains. There are 5 trains per weekday in each direction of which one train goes further directly to Berlin. In other cases it is possible to change to DB ICE or InterCity-trains between Hamburg and Berlin. This service is very fast and frequent.

From Oslo there no direct trains to Copenhagen. There are 4 trains per day and direction between Oslo and Gothenburg with NSB InterCity-trains. In Gothenburg mostly it is possible to change to regional Öresund trains to Copenhagen or SJ X2000-trains to Copenhagen. There are 20 regional departures and 3 X2000 departures between Gothenburg and Copenhagen.

There are also direct Night trains between Copenhagen and Köln sometimes with wagons also to Amsterdam and Basel by DB Night Train. These trains go via the fixed link at Stora Bält and Padborg and also stop in Hamburg but not in a proper time for travels between Hamburg and Copenhagen. There are also Night trains between Malmö and Berlin via the ferry line Trelleborg-Sasnitz by SJ Night train. This service is not daily and there is no service in winter time. There are also daily Night trains between Stockholm and Malmö.
Figure 4.1. Scandria passenger rail corridors 2010 (KTH).
Figure 4.2. Scandria long distance passenger rail network 2010 (KTH).
4.2 Passenger flows

This section describes journeys from Sweden to its closest neighbours in Europe; those countries where it might be possible to choose the train in the future with faster lines. It is primarily Germany that can come into question for both business and private travel, and under those premises southern Sweden may be of more interest than the Stockholm area even if the north of Germany will be able to be reached by train from Stockholm in a reasonable time when the Europe Line is completed. The countries that are of interest here are those to which passengers can continue their journeys from some node on the continent, e.g. Belgium, Holland, France, Great Britain, Switzerland, the Czech Republic, Austria and Poland.

A review was made in 2008 of total travel and travel using different means of transport to these countries, based mainly on data from the Scandinavian Travel Model (STM) and airport figures. The values are uncertain and must be interpreted with caution; it is really only the airport figures that are up to date and accurate, even if they are subject to the problem of transfer traffic. However, it is possible to get a rough picture of the travel in question, see figure 4.2-4.3 and table 4.1.

The table shows that a total of approximately 10 million long distance journeys were made to Denmark, 6 million to Germany, 2 million to Holland-Belgium, 2 million each to France and England and 0.5-0.7 million each to Switzerland, the Czech Republic, Austria and Poland. The car accounts for approximately half and air for about 30%. Other journeys, which can be either by coach or by ship, account for 15% and the train for just below 2%. It should be borne in mind that a large proportion of journeys by car are holiday trips during the summer when people travel around Europe. The figures also include people from other countries who travel to Sweden.

A rough division of travel has been made in Germany. Travel to the north of Germany (Hamburg-Hanover) is estimated to amount to a total of 1 million journeys and to eastern Germany also 1 million, Berlin being the primary destination. Most journeys are probably to the Ruhr, which is estimated to account for approximately 2 million journeys. Journeys to southern Germany are estimated to total just under 2 million.

Journeys by air to the countries and to the major airports in Sweden’s immediate neighbours in Europe are shown in table 3. Approximately half of all journeys by air are business trips and for the other modes of transport the proportion is 15-20%. Air travel is strongly concentrated to the major cities; approximately 75% of journeys go to the major airport, which is often also the capital. This is due both to the fact that the airports are located there and that they are the primary destinations, and that they act as hubs in the air network.

In Sweden, 80% of the journeys to the capitals are made from Arlanda and 20% from Landvetter, but these figures also include domestic transfer flights where passengers transfer at these airports. Be that as it may, air travel at both ends is capital city oriented while the car probably has a wider pattern. The train might be able to act as something in-between, naturally with good accessibility to the major towns and cities but also to medium-size places along the lines.

Weighing together the geographical picture on the map and the total travel data, it is clear that there is a good foundation for train traffic from the south of Sweden and Denmark to Hamburg and on to Cologne and Brussels, from where both Paris, London and Amsterdam can be reached. From Hamburg it is also easy to travel to Berlin.
Figure 4.3: All travels to and from Sweden to Denmark, Norway, Germany, Netherlands and Belgium assigned to the rail network (KTH).
Figure 4.4 Estimated total number of travels in millions with all modes from Sweden to some countries and regions in Europe 2009 (KTH).

Table 4.1 Journeys from Sweden to the near part of Europe. Source: KTH Compilation of data from the STM model and destination statistics of the Swedish Civil Aviation Administration.

<table>
<thead>
<tr>
<th>Country</th>
<th>Rail</th>
<th>Car</th>
<th>Övrigt</th>
<th>Air</th>
<th>Total</th>
<th>Share air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>0,2</td>
<td>7,2</td>
<td>1,8</td>
<td>1,7</td>
<td>10,9</td>
<td>16%</td>
</tr>
<tr>
<td>Germany</td>
<td>0,1</td>
<td>3,2</td>
<td>1,2</td>
<td>1,8</td>
<td>6,3</td>
<td>29%</td>
</tr>
<tr>
<td>Belgium</td>
<td>0,0</td>
<td>0,2</td>
<td>0,1</td>
<td>0,4</td>
<td>0,6</td>
<td>59%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0,0</td>
<td>0,3</td>
<td>0,1</td>
<td>0,9</td>
<td>1,3</td>
<td>67%</td>
</tr>
<tr>
<td>France</td>
<td>0,0</td>
<td>0,6</td>
<td>0,3</td>
<td>0,9</td>
<td>1,9</td>
<td>48%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0,0</td>
<td>0,2</td>
<td>0,3</td>
<td>1,4</td>
<td>1,8</td>
<td>74%</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0,0</td>
<td>0,1</td>
<td>0,1</td>
<td>0,4</td>
<td>0,6</td>
<td>67%</td>
</tr>
<tr>
<td>Chez/Slovak</td>
<td>0,0</td>
<td>0,3</td>
<td>0,1</td>
<td>0,2</td>
<td>0,5</td>
<td>27%</td>
</tr>
<tr>
<td>Autsria</td>
<td>0,0</td>
<td>0,2</td>
<td>0,1</td>
<td>0,3</td>
<td>0,7</td>
<td>46%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0,4</td>
<td>12,3</td>
<td>4,0</td>
<td>7,9</td>
<td>24,7</td>
<td>32%</td>
</tr>
</tbody>
</table>
4.3 Rail competitiveness

In order for the train to be an alternative for international journeys by day-time trains, a journey time of 5 hours is required for normal private and business journeys. In the case of night trains, 15 hours is acceptable if the journey is made between 5 pm and 8 am. This primarily applies in competition with the car and coach; in competition with air travel, journey times must be shorter. In addition, the train can also be used for tourist trips, but here it is not the journey time that is crucial but rather the converse; the trip itself must be part of the experience.

Today, the train can be an alternative for journeys between the Stockholm region and Copenhagen and from western Sweden to large parts of Denmark. It is also possible to travel to the whole of Denmark and to the north of Germany from Skåne. Travel to and from southern Sweden to Copenhagen and Zealand has increased rapidly, not least due to the construction of the Öresund Bridge, which shows that the train can be an alternative with shorter journey times. In other respects, the train is used for occasional private and business trips over longer distances and for tourist trips, for example with an InterRail card during the summer.

As late as the beginning of the 1990s, there was a relatively extensive network of international train routes, among other things with direct sleeper cars also from Sweden. Airlines’ international routes gradually improved at the same time as deregulation of the railways led national operators to rationalise and reduce their increasingly unprofitable international routes. In this situation, the railway companies found it hard to cooperate and could not compete either. Possibilities to get information, book and purchase through-tickets also deteriorated. The establishment of low-price air travel in the late 1990s meant that international train traffic could not even compete with low prices.

High-speed trains have on the other hand improved the train’s competitiveness on many important routes on the continent and the short journey times have made the train market leader on many important routes. More flexible pricing has meant that the train can compete with low-price air travel. The possibility to get information and book tickets has also improved with access to the web, even if there is still a long way to go. At the same time, the climate issue has led to air travel being increasingly questioned and travellers beginning once again to choose the train. In recent years, charter trips by train have also begun to be arranged.

The high-speed network in Europe has gradually been extended, first with national lines, and the network has later been joined together with international routes. Figure 8 shows that there are already short journey times between many large cities on the continent. Having reached Hamburg, it is possible to travel to Berlin, Munich, Prague and Cologne inside about 4 hours. Once in Cologne, one can reach Amsterdam and Brussels in less than 3 hours and from Brussels Paris is 1½ hours away and London 2 hours and 20 minutes. One problem, however, is that it takes 11 hours to reach Hamburg from Stockholm and there are also no direct lines. It takes almost 24 hours to reach the most distant cities by train by the fastest route today.

4.4 Relative travel times

The travel times and frequencies have been invented in a database for all modes, as described in chapter 1.3. To compare the travel times by rail and other modes a calculation has been made of the average speed from city to city by road distance for the fastest connections. Figures for some city-pairs are shown in figure 4.6-4.7. More detailed data is presented in the supplement.

Average speed in the corridor from Stockholm by train is always better by train than by car. Between Stockholm and Malmö and Copenhagen it is also competitive by air under some conditions. The
average travel speed is 130-140 km/h because of X2000 high speed tilting train and rather good infrastructure. By car travel speed between these cities are about 90 km/h including some breaks. By air the travel speed is about 200 km/h from city to city including feeder transports. Anyhow, travel times by trains are 4.5-5 hours are too long for business travels over the same day compared with air 3-3.5 hours. Travel times by train maybe convenient for private trips and for more than one day stay on business trips.

To northern Germany the average speed by train is lower, about 100 km/h because of changing train in København and transferring the trains by the ferry line Rødby-Puttgarden. The ferry connection also affects car travel times which are even lower, about 80 km/h. Here also average speed by air is higher, about 250 km/h, because of longer cruising distance. The long travel time and the need to change train in København will make it possible to compete with a direct night train especially if it will cover both Hamburg and Berlin.

In the contrary from the corridor from Stockholm the average speed in the corridor from Oslo by train is always lower by train than by car. Average speed by train is only 60-80 km/h compared with car 80-90 km/h. Compared with air with an average speed of 200 km/h or more this is not competitive, especially taken into account that there must be change of train in both Gothenburg and København.
Figure 4.5 Travel times by rail from Stockholm to some cities in Europe 2010 (KTH).
Figure 4.6 Average speed from city to city by car, rail and plane from Stockholm to some cities 2010.

Figure 4.7 Average speed from city to city by car, rail and plane between some cities 2010.
5 Functional Corridors for freight

5.1 Freight corridor functions
The corridors will be defined by the demand on the one hand and by the transport system on the other hand. In this project the regions are a demarcation from the beginning, but the demand and the transport system have also a wider purpose. Along the corridors there are local and regional markets, national markets and international markets. There are different markets for freight and passenger transport. In this chapter we will try to describe the main functions of the corridors today and their potential for tomorrow.

For rail freight long distance and international transport are important. There are almost no local or regional transports because the capillary rail system is not so dense and the economies of scale makes rail transport more efficient over longer distances. This is even more evident for ocean shipping. Trucks have in reality a technical monopoly on short distance transports of less than 100 km but have also had an increasing market share on longer distances.

In the Scandria corridors the most important function is for international freight from Hallsberg to Hamburg (Maschen). Most of the freight originates in northern and central Sweden and continues beyond Hamburg to Ruhr in Germany, Italy and other destinations. There are smaller international flows between Norway and Gothenburg, Gothenburg and Denmark and Denmark and Germany and the European continent. There are also smaller flows between northern Germany and Skåne via the ferry connection Sassnitz-Trelleborg, but most of the freight goes by semitrailer on the ferry and is loaded onto railway wagons in the ports.

The international function in the rail corridor is strong for freight between Sweden and Germany and the European continent but rather weak between the other countries. The national freight function is also rather strong in Sweden.

5.2 Potential for improved rail freight transport
From the shipper’s point of view there are problems with the dependability of rail transport and to get competitive rail freight for international transports. The latter problems may be solved when the deregulation of freight will be fully implemented in practice and when the operators can offer seamless and reliable transports at the right price. This is a question of politics and management and will not be discussed in this chapter. In this chapter some steps to get a common technical standard will be proposed.

Increase train lengths to 835 m in the short term between the gateways of southern Sweden and its major marshalling yards: Malmö, Hallsberg, Sävenäs (Gothenburg) and Borlänge as well as Stockholm. Increase train lengths to approx. 1670 m on the main corridors of Germany and Scandinavia in the long term.

Unify the national brake rules and brake tables in Germany and Scandinavia.

Establish additional freight train paths for 120 km/h during daytime in areas where passenger traffic dominates. The number of freight cars approved for this speed, empty or loaded, is growing steadily.

Establish a large, rectangular loading gauge for new construction and upgrading of existing railway lines. Considering the normal catenary heights of 5.3 to 5.5 m in Germany, a height matching the
Swedish C loading gauge at 4.83 m appears feasible. A width of 3.15 m would correspond to what is now in effect in Denmark and Germany.

Build subgrades and track for 25 tons axle load or heavier for new construction and upgrading of existing railway lines. 25 tons or heavier is already being applied on portions of several national railway networks in Europe, including those of Finland, Germany, the Netherlands, Norway, Sweden and the United Kingdom, as well as wagon fleets in Austria, Belgium and leasing companies.

Raise meter loads to 8.3 tons/m between the gateways of southern Sweden and connecting lines at Halmstad and Hallsberg.
Figure 5.1: Scandria rail corridors functionality for freight transports today.
6 Functional corridors for passenger services

6.1 Passenger corridor functions

For passenger rail regional, interregional as well as international transport are important. In contrast to freight, international transports are a small part and interregional transports are dominating along the corridors. Around and between the urban areas there are also regional transports.

In the Scandria corridor the most important function for the long distance between Stockholm and Skåne and between Gothenburg and Skåne. There are also an international function between Stockholm and Copenhagen and the regions in between and between Gothenburg and Copenhagen. The corridor also includes an important regional function which exists between and around many Cities south of Stockholm, South and north of Gothenburg and south of Oslo. A very important regional function exists also in region Skåne together with Själland which also is an international short-distance market. Also in Germany there are regional markets around Hamburg and Berlin and of course between Hamburg and Berlin.

For passenger the interregional and regional functions are the strongest. There also exists an international regional market between Sweden and Denmark. The function between Norway and Sweden and between Denmark and Germany are rather weak. Internal function in northern Germany is also strong in between some cities.

6.2 Potential for improved passenger rail transport

For passenger rail transport there are both technical problems and operational problems. From the customers point of view the biggest problems long journey times, lack of direct connections and difficulties to get information and by tickets for international trips.

The weakest links

The weakest link in the Stockholm-Berlin corridor is the train connection between Copenhagen and Hamburg/Berlin. There are no direct trains and the frequencies and departures are not harmonized. There are different operators and no guarantee of connection when all travellers have to change trains.

In the Oslo-Berlin corridor the weakest link is between Oslo and Gothenburg. Both the frequency and the average speed are low, in practice lower than the fastest bus-connection. The fact that there always also is necessary to change train in Gothenburg also affect rail competitiveness. Between Copenhagen and Hamburg/Berlin the problems are the same as for the Stockholm corridor. From Gothenburg to Copenhagen the frequency is rather high and the average speed is acceptable, but there is a very high standard motorway to compete with all the way.

From the customer point of view also the problems to get accurate information and to easily by a ticket to a proper price also is a big problem. There is very good information at the db.de site even about international travels but for most of people living outside Germany this is not probably known. However it is not possible to buy international tickets directly from this site and the possibility to by international tickets by the national railway companies is restricted to a few relations.

Most of the network is electrified but the line from Copenhagen via Rødby to Hamburg is not electrified yet. There is a different electrical system in Denmark compared with Sweden, Norway and Germany who have the same. There are also different signalling systems in all countries except Sweden and Norway who have very similar systems.
Figure 6.1: Scandria rail corridors functionality for passenger transport today.
7 Future development of the freight transport system

7.1 Scenarios for future development

The load on the railway network is greater than ever. On several sections it is impossible to add more trains when the demand exists and the risk of delays is significant under high load conditions. This is especially true on the Southern Main Line between Stockholm and Malmö and the Western Main Line between Stockholm and Gothenburg. These lines have extensive heavy freight traffic, as well as high-speed trains travelling at line speed, and regional and local trains on many sections. The differences in speed between the trains are considerable, leading to lower capacity and greater sensitivity to disruption.

These are the major routes as regards total demand for freight and passenger transportation in Sweden. Stockholm to Gothenburg and Malmö/Copenhagen and places in-between are the biggest markets for long-distance transportation and train, air and car traffic is considerable.

In Sweden different scenarios and forecasts have been made for the future development of the main lines, affecting passenger transports as well as freight transports. In this chapter some results of the forecasts will be presented focused on freight between Scandinavia and Europe. The following scenarios will be used:

- A basic forecast for freight transports in Sweden for the year 2030 with planned investments in infrastructure in Sweden. Does not include the fixed link at Fehmarn Belt. Developed rail systems on existing infrastructure via rail ferries and via the Öresund bridge and Padborg. Made by KTH for the Swedish capacity investigation 2011.

- A special forecast for the consequences of the Fehmarn Belt fixed link and upgraded connected infrastructure. This forecast was originally made for 2020 but has later been prolonged to 2030.

- A Scenario for the year 2030 called “Capacity and deregulation” (CAP) with higher market share for rail according to the EU targets in the white paper from 2011 towards 2030. This scenario includes a separate real high-speed network in Sweden and international rail freight transport corridors including the fixed link at Fehmarn Belt.

The results of the basic forecast and the CAP-scenario are presented in section 7.3 as the number of freight trains on the Swedish railway network and connecting line to Norway, Denmark and Germany. The results of the forecast for the Fehmarn Belt connections 2020 is presented in section 7.2 below.
Figure 7.1 show the most important transport flow by rail between Scandinavia and northern Germany. There will be an increase of about 30% even in the basic forecast to 2030. As a consequence of the fixed link across Fehmarn Belt the flows will be restructured from the rail via Padborg to Fehmarn Belt. This will probably also affect the ferry lines. In 2014 the axle load via Padborg will be raised from 20 t to 22.5 ton because of upgrading the bridge at Rendsburg. Already this will affect the ferry lines which are now the only connection from Sweden to Germany with 22.5 tons axle load.
7.2 Effects of the fixed link across Fehmarn Belt

The fixed link across the Fehmarn Belt, planned for completion in 2021, will shorten the transport route between Sweden and the continent by about 180 km. It will enable rail freight to be transported faster and at lower operating costs. Since this is of great importance for future railway traffic from Sweden to the continent, a specific forecast has been drawn up of the effects of the Fehmarn Belt link.

An earlier forecast looked at the effects of the link from 2008 to 2020. Forecasts of transportation costs and times have been made for three alternatives. These forecasts have then been extrapolated to cover the period up to 2030.

Figure 7.1 shows the total freight quantity in international rail traffic. This also includes transportation to some countries not concerned by the fixed link to the Fehmarn Belt: Norway, Finland, Russia, Great Britain and the Baltic states. Some parts of Europe where links via the Fehmarn Belt can hardly compete have not been included. This volume amounts to 3.4 million tons in base alternative 2020; the remainder, 9.7 million tons, constitutes the potential quantity of rail freight that can be transported via the Fehmarn Belt.

Alternative 1 has the same charges across the Fehmarn Belt as the Great Belt but the shorter route means that transportation costs from Sweden to the continent will come down by 15% and transportation time by 10%. The potential freight quantity then increases by 2.7 million tons to 12.5 million tons. In Alternative 2, the infrastructure is developed more extensively so that the average speed of the freight trains increases, shortening transportation times by 21%. The potential volumes then increase by 3.7 million tons, making a total of 13.4 million tons. In Alternative 3, the same total transport cost is assumed as via Padborg, which means high charges across the Fehmarn Belt but also a more substantial shortening of the transportation time of 21%. In this case, the potential freight volume increases by 1.9 million tons to 11.6 million tons.

The forecast shows that the transport cost and time are of great importance not only as regards the railway’s competitiveness, but naturally also Swedish industry’s competitiveness. In the capacity and deregulation alternative, a fixed link across the Fehmarn Belt is a prerequisite. The freight volume in this case is even greater but approximately half of the 7.4 million ton increase compared to the base alternative is due to the effect of the Fehmarn Belt link with normal prices and transportation times.

The effect of the Fehmarn Belt link is thus that rail freight transportation in Sweden increases by approximately a further 10% in the base alternative. It is primarily export freight that comes from northern and central Sweden and that is transported on the Southern Main Line and to some extent on the West Coast Line. In the capacity and deregulation alternative, the Fehmarn Belt is included from the outset and the transportation effort by rail in Sweden increases by 80% compared to 2010.
Table 7.1: Forecast for rail freight transports from Sweden to Europe 2020 with different alternatives for the Fehmarn Bält connection and for an alternative with increased market share for rail.

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Miljons of tonnes</td>
<td></td>
<td>Basic-</td>
<td>Alt 1</td>
<td>Alt 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>alternative</td>
<td>Normal</td>
<td>Fast</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compare 2008</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compare 2020 basic alternative</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

7.3 Calculations of the load on the railway network with different prerequisites in 2030

A method has been developed to calculate the number of freight trains distributed over the railway network in a future situation. The starting point is the number of freight trains distributed over the railway network, in this case in 2010, and matrices for the freight volumes in tons between the counties for the base year and the forecast year. The freight volumes are distributed over the railway network using VISUM according to the shortest route time-wise. A ratio is formed between the forecast freight volume and the freight volume for the forecast year on each link. On the basis of this ratio the number of freight trains is calculated on every link for the forecast year. Special routines have been developed to calculate the number of freight trains on links within an area that have no through traffic.

It is also possible to insert new links in the system and send the freight along new routes if transportation is faster due to increased capacity. In this case, the Bothnia Line, for example, which had no through traffic in 2010, has been added. The number of freight trains has also been redistributed due to the planned capacity-increasing measures such as the Hallandsås Tunnel and the fixed links across the Fehmarn Belt. It is also possible to adjust the number of freight trains depending on whether the train masses change but this has not been done in this case.

The railway network is divided into links or “presentation lines” that have also been used in the Capacity Analysis of the Swedish Rail Network report (KTH, 2009) [9]. For this purpose, some of the presentation lines have been further divided and the network has been complemented with links to neighbouring areas in other countries. There are a total of 167 presentation lines. The results are shown here on maps.
In this case, the base year of 2010 is shown together with a base forecast for 2030 (base alternative 2030) and a forecast for the capacity and deregulation alternative in 2030 (capacity alternative 2030). As is clear from the above, the base alternative does not involve any major improvements in train traffic supply while the capacity and deregulation alternative contains substantial improvements of both capacity and the quality of rail freight traffic. The capacity and deregulation alternative gives the railway a greater market share, which comes close to fulfilling the EU's objective of a greater proportion of freight transported by rail and intermodal transportation.

The results are shown in Figure 7.2. The maps show the number of planned train paths per day and direction, the actual number of trains operated is usually a little lower. All freight trains are included in the base situation, thus also local freight trains that travel along a presentation line. The 2010 maps show quite clearly the major lines with many trains from northern to central Sweden and from there on down to Hallsberg and then to Gothenburg and Malmö.

Certain structural changes will be made over the years up to 2030. The full length of the Bothnia Line is in operation by through freight trains (probably from 2013) and traffic between northern and central Sweden is distributed over the Northern Main Line and the Bothnia Line so that the southbound freight trains use the Bothnia Line, where gradients are less steep, and the northbound freight trains use the Northern Main Line, which has steeper gradients. The reason for this is that the southbound freight trains carry heavier loads of for example export freight and the northbound freight trains are lighter as they contain more empty wagons.

The freight trains from Dalarna to Gothenburg have also been redistributed so that more trains take the route west of Lake Vänern via the Bergslagen Line instead of the Western Main Line. Some trains continue on the West Coast Line which will have more capacity when it is double-track all the way. Some redistribution has also been made from the Southern Main Line. In the Stockholm area, some trains are redistributed from the Hallsberg-Katrineholm-Stockholm line to the Hallsberg-Västerås-Stockholm line.

Traffic to the continent is redistributed such that most takes the route via the Fehmarn Belt fixed link instead of the Great Belt and Padborg. Some traffic is also redistributed from ferries to the fixed link. Ferry traffic to Germany and Poland remains but is assumed to be concentrated to Trelleborg.

Generally speaking, freight transportation by rail increases by 30% in the base alternative and by 80% in the capacity and deregulation alternatives, which means that the differences between the numbers of freight trains are considerable. In practice, the larger freight volumes in the capacity and deregulation alternatives provide a basis for longer, heavier trains and the increase in this case may therefore be somewhat smaller. It is quite clear, however, that the structure with increased demand for train paths on the lines that already today have many freight trains is strengthened in the capacity and deregulation alternatives. Possibilities exist for further redistribution but can only reduce the need for capacity on the main lines to a limited extent.
Figure 7.2 Number of freight trains calculated for 2010 and 2030 with a basic forecast and with increased rail market share.
8 Future development of the rail passenger transport system

8.1 Scenarios for future passenger rail system

In connection with the government commission on high-speed trains in Sweden 2009 [8],[40], scenarios and forecasts have been made for three different ways of expanding the rail network:

1. A basic forecast with proposed investments up to and including 2020, that most closely corresponds to what could be estimated from the planned measures as they stood in 2009.

2. An alternative with upgraded mainlines to 250 km/h Stockholm–Gothenburg and Stockholm-Malmö main lines has been analysed.

3. An alternative with building of dedicated high-speed lines for 320 km/h, the Götaland Line and the European Line.

With an expansion of the main lines, travel increases by 18 % in the whole of Sweden compared to the basic forecast. The findings from the studies indicate that most train passengers come from air travel.

The forecasts show that building of dedicated high-speed lines has significant effects. Rail travel in the whole of Sweden increases by 50 % compared to the basic forecast with normal investments up to and including 2010. The new train passengers come from car and air and new travel.

Upgraded main lines to accommodate express trains running at 250km/h with more tracks and crossing stations was estimated to cost SEK 54 billion. Building of dedicated high-speed lines with separate new 320 km/h tracks Stockholm-Nyköping-Norrköping-Linköping-Jönköping and from there both to Gothenburg and to Helsingborg/Hässleholm-Malmö-Copenhagen is estimated to cost SEK 125 billion. In the latter case, capacity is also freed up for freight trains and regional trains on the main lines.

The high-speed alternative gives a very large consumer surplus through time gains and also a very high producer surplus in the train traffic. Some of the producer surplus can be used to finance the infrastructure. The consumer surplus in the main line alternative is one fifth as large and the producer surplus half as large as in the high-speed alternative. The high-speed alternative had the highest socioeconomic profitability.

If the main lines are to be expanded to four-track over their entire length, this will cost a further SEK 125 billion or a total of SEK 180 billion, i.e. more than the high-speed alternative. This gives the same capacity as in the high-speed alternative but with longer journey times and substantial disruptions along the existing line during the long expansion period. It is thus very clear that the greatest socioeconomic efficiency is obtained through expanding the high-speed lines as proposed by the investigator.
Figure 8.1 The dedicated high-speed lines in Sweden is suggested to add capacity on the western mainline Stockholm-Gothenburg and the southern mainline Stockholm-Malmö-Copenhagen. With a common line from Stockholm-Södertälje to Jönköping and from there one line to Gothenburg and one line to Helsingborg/Malmö there will be fast and reliable track for high speed trains and at the same time there will be more capacity for freight trains and regional trains on the old mainlines.

From Malmö the trains can use the Öresund bridge to go to Copenhagen but there is also a long term option for a new fixed link between Helsingborg and Helsingør and further on to Copenhagen. From Copenhagen the trains can continue to Hamburg and Berlin via the fixed link at Fehmarn Belt.
Figure 8.2: Travel times by rail from Stockholm to some Cities in Sweden, Denmark and Germany with high speed lines. Source: Calculations for the Swedish High Speed investigation by KTH 2010.

Figure 8.3: Travel times by rail from Oslo with high speed lines in Norway. Source: KTH evaluation of the Norwegian investigation of HSL in Norway and to Sweden 2012.
8.2 Long term solution for Sweden

Further investigations have been made of the capacity situation on southern main line between Katrineholm and Hässleholm i.e. in the Gröna Tåget (Green Train) project. The conclusion is that it is very difficult to increase the speed of the high speed trains to 250 km/h without increasing the delays even with investments in more passing loops. In the last years new regional train systems and new regional stations has been established along the southern mainlines which make it difficult even to operate today’s high speed trains without delays. Therefore SJ has prolonged the journey times for the high speed trains with 10-15 minutes between Stockholm and Malmö from 4:25 to 4:35-4:40.

The Swedish Capacity Investigation made by Trafikverket 2012 has proposed to build the first part of the high speed lines between Stockholm/Södertälje and Linköping “Ostlänken” and Gothenburg-Borås. In august 2012 the Swedish government also proposed that this links shall be built, starting at 2017 and competed at 2028. However, they proposed that it will be built for 250 km/h instead of 320 km/h which is the speed those links has been planned for until now. This is now discussed in Sweden and we will wait and see what will come out of this discussion in the final end.

In the long term perspective building of dedicated high speed lines seems to be the right solution if the railway will have an important share of passenger transports as well as freight transports.

8.3 The Norwegian high speed investigation

There has also been a High Speed Line investigation in Norway that was presented in January 2012. The investigations were made of the most important lines in Norway and also of the lines from Oslo to Gothenburg and from Oslo to Stockholm. The proposal was to build dedicated double track lines for a maximum speed of 330 km/h. The lines to Sweden have also suggested to be adopted for freight transports with a maximum grade of 12.5 ‰.

For the Scandria project the link between Oslo and Gothenburg is the most important. Today for passenger transport travel times are long and frequency is low so rail cannot even compete with buses. For freight transports there is approx. 10 millions of tons going by truck between Oslo and Gothenburg and a great deal will continue towards Denmark and Germany.

8.4 Planning of new links in Denmark

To provide capacity for increased services, construction of the 60 km high-speed (250 km/h) mixed passenger and freight line Copenhagen-Ringsted via Køge is in progress. The new line will relieve the older mainline west from central Copenhagen when it opens in 2018. The transit freight between Sweden and Germany will thus interfere less with the intense regional services on Zealand to the Danish capital (Denmark’s fastest railway, 2012).

Also the Öresund link (Malmö-Copenhagen) needs strengthened capacity. Planning in Denmark is in progress for some construction to increase the capacity for freight and passenger services around Kastrup (Copenhagen airport) station (Kapacitetsudvidelse på Øresundsbanen, 2012). In the longer term, serious capacity problems with conflicts between the expanding regional services on one hand, and long-distance passenger and freight on the other, could be expected which has not yet any solution.

The Fehmer Belt connection which is scheduled to open in 2021 also requires extension from single track to double track and electrification of the mainline south from Ringsted to the sound crossing and
the tunnel. Top speed for the whole link is considered to be either 160 or 200 km/h (Femern Bælt - danske jernbanelandslæg, 2012). In 2012, an investigation deemed the older single track Storstrøm bridge on this link to replacement rather than rebuilding after damages occurred, and what have could been a serious bottleneck will most likely be replaced by a new double track bridge with adequate capacity (Storstrømsbroen, 2012).

In the longer term, a new Öresund connection between Helsingborg and Elsinore could be an important link for both passenger and freight services. If constructed, a new orbital primarily freight corridor (Ring 5 Elsinore–Køge) bypassing the congested coast line between Elsinore and Copenhagen, and central Copenhagen, would be desirable. Such a connection would also relieve congested sections in southern Sweden and the existing Öresund link (Korridoren Femern–Öresund, 2010). High-speed trains should however preferably stop in the city centre to achieve accessibility to main destinations by foot and the public transport hub, and capacity on access lines to the Copenhagen central station for planned services need to be secured.

8.5 Effects of high speed lines from Scandinavia to Europe

Extension of the high-speed line from Sweden to the continent would have great significance when it comes to reaching the European continent by train. Figure 8.4 show possible journeys by high-speed train with the Europe Line completed. If the Europe Line is built, it will be possible to travel from Stockholm to Copenhagen in less than 3 hours and if the high-speed line is extended to Hamburg, it will be possible to travel there in 4½ hours. From there, travellers can reach the rest of Europe. The entire area described above, including cities as far away as London, Zurich and Vienna, can be reached within 15 hours from Stockholm; with night trains, this could be an alternative. Travelling times from Gothenburg and western Sweden are roughly the same, while journeys from the south of Sweden are approximately 2 hours shorter.

It is thus of utmost importance that the high-speed line is extended not only in Sweden but also via the fixed link over the Fehmarn Belt, which is due for completion in 2021. It is not just to be able to travel from Stockholm to Hamburg for example, but also to form a transport corridor from Sweden and Denmark and on to the continent, linking many large cities where both many long and short journeys overlay each other and together form a large market.
Figure 8.4 Travel times by rail from Stockholm to some Cities in Europe with real high speed trains in a scenario for 2030.
8.6 Capacity with high speed lines

If a real high speed line and the European line for high-speed trains between Stockholm-Jönköping-Gothenburg/Malmö-Copenhagen are built, most of the express trains can be removed from the Western and Southern main lines. In addition to extremely short travelling times and greater capacity and punctuality in passenger traffic, capacity is also freed up on the main lines for freight traffic and regional trains. Simulations show that it is possible to operate 2-3 times more freight trains during the day.

More capacity for freight transportation on the main lines also means that Swedish industry can be offered cost-effective transportation of high quality that is sustainable in the long-term. In a situation where truck traffic is becoming more expensive as a result of rising fuel prices and road tolls, it is important that the export industry has alternatives to turn to. Researchers are also agreed that we must both make our existing modes of transport more efficient, change fuels and switch to more energy efficient modes of transport to a greater extent to be able to meet the climate crisis.

Customers are demanding rail transportation to an increasing extent. This is partly due to the fact that the environment has become a more important factor in the choice of transport mode. The railway is the most energy efficient transport mode due to its low rolling resistance: this applies especially in the case of the large transport volumes carried on the main lines. Electric railways can be supplied with electricity produced by any means from wind power to nuclear power and can thus contribute to solving environmental and climatic problems.

The Western main line is very important to industry because of its link to the Port of Gothenburg, which is the only transoceanic port in Scandinavia. The Southern main line is very important as an artery for international traffic to the continent. Both lines are also very important for domestic freight transportation and passenger traffic. In practice, there is no capacity available today on the Western main line between Hallsberg and Gothenburg. The Southern main line is plagued by long delays that are the result of mixing different kinds of trains.

Denmark has decided to extend the permanent road and rail link over the Fehmarn Belt (between Rødby and Puttgarden) and it is scheduled for completion in 2021. This will make it possible for freight trains to take a shorter, non-stop, route between Malmö and Maschen in Hamburg and reduce the journey time from 8 hours to 6.

It takes a long time to plan, finance, take decisions and build railways in most countries today. Considering the competitiveness for the regions along the Scandria corridors it is important that decisions to build a high-speed rail network be taken as soon as possible in all countries and preferable coordinated with each other. Then we can ensure that the railway network will have sufficient capacity for both passenger and freight traffic and secure a transport system that is sustainable in the long term.
Figure 8.5 Capacity for freight trains with upgraded main-lines and real high-speed lines.
9 Existing strategic infrastructure plans

Existing infrastructure and operating practices are reviewed, as well as those improvements which are already included in the present plans. The national plans for infrastructure investment cover approximately a decade, and are generally updated after half that period. Of the plans now in effect, several were adopted recently. A summary follows:

- Finland: Transport Policy Guidelines and Transport Network Investment and Financing Programme Until 2020 [18];
- Sweden: National Plan for the Transport System 2010-2021 [21];
- Denmark: Political Agreement on a Fixed Link Across Femern Bælt [22], Agreements for a Green Transport Policy [23], Traffic Investment Plan 2009-2020, Agreement on Electrification of the Railway 2012;
- Fehmarnbelt: Treaty on a Fixed Link Across Fehmarnbelt [24];

The links considered are the mainlines of the north-south corridors, see Figures 1 and 2.

9.1 Route structure and new links

- The present route structure by rail and ferry is shown in Figure 9.1. Several new links are under construction or in the present plans:
  - Norway: an additional mainline Oslo-Ski to relieve the existing line from congestion, construction to begin in 2013;
  - Sweden: a tunnel through the Hallandsåsen ridge south of Halmstad, replacing an existing single track line with sharp curves, to be completed in 2015;
  - Denmark: a new mainline København-Køge-Ringsted to relieve the existing line København-Roskilde-Ringsted from congestion, to be completed by 2018;
  - Fehmarnbelt: a fixed link, a tunnel, Rødby-Puttgarden, for railway and highway combined. Compared to the land route via Kolding, the Rødby-Puttgarden link will save some 160 km between København and Hamburg, and more for points east or south of Lübeck. The new fixed link is slated to have capacity for 48 freight trains per day in each direction, as does the land route via Padborg [28];
  - Germany: a new eastern freight corridor Uelzen-Stendal-Leipzig-Regensburg on existing lines to relieve the existing corridor Uelzen-Göttingen-Würzburg-Nürnberg-Regensburg from congestion, to be implemented around 2019.
- All the new links mentioned above are to be electrified and double track. The route structure and connecting lines after 2021 are marked bold in Figure 9.2.
Figure 9.1 Cross-border railway routes of southern Scandinavia and northern Germany in 2012

Figure 9.2: Cross-border railway routes of southern Scandinavia and northern Germany in 2021.
9.2 Number of tracks

The majority of mainlines handling freight trains between Scandinavia and Germany are double track. Single track sections with plans for double tracking mentioned are:

- **Norway:** Sandbukta-Rygge (Såstad) to be double-tracked by around 2017, Haug-Onsøy proposed for double-tracking by 2023.
- **Sweden:** Trollhättan-Gothenburg double-tracking to be completed in 2012, Varberg-Hamra to be double-tracked by 2021, Båstad-Ångelholm (Hallandsåsen) double-tracking to be completed in 2015, Hallsberg-Degerön partial double track to be built by 2021, Motala-Mjölby double-tracking to be completed in 2012, Flackarp-Ariöv to be quadruple-tracked by 2021.
- **Denmark:** Vamdrup-Vojens to be double-tracked by 2015, Tinglev-Padborg, Køge-Næstved, Vordingborg-Orehoved (Storstrom bridge) to be upgraded or rebuilt by 2021 possibly with double track, Orehoved-Rødby to be double-tracked by 2021.
- **Germany:** Puttgarden-Fehmarnsund to be double-tracked by 2028, Fehmarnsund-Bad Schwartau to be double-tracked by 2028, Uelzen-Stendal to be double-tracked by around 2017.

9.3 Speed

Planned speed upgrades include:

- **Sweden:** Göteborg-Trollhättan 200 km/h (2012), Båstad-Ångelholm 200 km/h (2015), Malmö-Trelleborg to 160 km/h (2015 estimated):
- **Denmark:** Ringsted-Odense to 200 km/h, Ringsted-Vordingborg to 160 km/h; freight 120 km/h
- **Germany:** (2018) Puttgarden-Bad Schwartau to 160 km/h, (2013) Rostock-Berlin to 160 km/h

For freight wagons are increasingly being built for 120 km/h operation, even loaded. Denmark plans to increase the number of freight train paths at 120 km/h as a way of accommodating more freight trains daytime, slotted between faster passenger trains.

9.4 Power supply

With the present route structure per Figure 1, all the mainlines presently handling freight trains between Scandinavia and Germany are electrified. The power supply is shown below, together with the situation for lines connecting to the Fehmarnbelt fixed link:

- **Denmark:** 25 kV, 50 Hz; Ringsted-Rødby to be electrified by 2021, electrification of Køge-Næstved to be investigated,
- **Germany:** 15 kV, 16.7 Hz; Puttgarden-Bad Schwartau to be electrified by 2028, Lübeck-Bad Kleinen identified as candidate for electrification.
9.5 Traffic control system

EU has decided that ERTMS shall be implemented when building new railways and doing major re-investments. Also the six border crossing freight corridors in Europe shall be equipped with ERTMS, for example corridor B, Stockholm – Naples. According to a commission decision in 2009 the implementation of ERTMS in these corridors be done no later than 2020. The progress of the implementation is formally described in the “ERTMS Atlas 2012” issued by UIC.

In Sweden ERTMS is the focus on newly built or upgraded railways in the northern part of Sweden, the Botnia line (Umeå – Västersasby) in service since 2010, and the complete connection Sundsvall – Umeå was completed 2012. The Swedish part of corridor B will be implemented 2020.

Norway will have a pilot line on the Østfoldabanen between Sarpsborg – Ski ready 2014 and have a national implementing plan 2014 to 2023 for the rest of the network. Connection with Sweden via Charlottenberg will be reached 2016.

Denmark has decided to implement ERTMS on all mainlines between 2016 and 2021.

Germany has an extensive plan for building high-speed lines to be in operation between 2014 – 2019. For the German part of the EU freight corridors, the German government has decided to implement ERTMS using STM during a transitional period. This makes it possible to use existing trackside equipment together with ERTMS equipped rolling stock.

For existing lines, preliminary schedules indicate the following implementation schedule for ERTMS Level 2:

- Øresund: installation prepared, schedule not announced;
- Denmark: København-Ringsted-Rødby by 2019 and Ringsted-Kolding-Podborg by 2020;
9.6 Gradients
The plans for new lines and tracks will in some specific cases lower the grades as follows:

- Sweden: Halmstad-Ångelholm 10 ‰ by 2015;
- Denmark: Via Fehmarnbelt: Plans to not exceed 12.5 ‰.

9.7 Axle load
The plans for upgrading mainlines connecting Scandinavia and Germany to permit higher the axle loads are shown below:

- Norway: Oslo-Kornsjø 22.5 tons, strengthening to 25 tons ongoing [11];
- Øresund: 25 tons permitted from 2011;
- København-Køge-Ringsted not announced;
- Germany: 22.5 tons, Rendsburg bridge strengthening from 20 tons to 22.5 tons to be completed in 2014 [36], Rostock-Berlin strengthening from 22.5 tons to 25 tons to be completed in 2015 [37].
- Existing mainlines in Finland, southeastern Norway and Sweden are gradually being upgraded to 25 tons axle load where there is a demand for heavy freight transport. New lines in Sweden are being planned for 30 tons.

9.8 Meter load
The mainlines connecting Scandinavia and Germany permit the meter loads shown below:

- Øresund: 8.3 tons/m permitted from 2011;
- Denmark: København-Køge-Ringsted not announced;
- Germany: Rendsburg bridge strengthening from 6.4 tons/m to 8 tons/m to be completed in 2013 (for simultaneous use of one track only) [36].
- Existing mainlines in Sweden are gradually being upgraded to 8 tons/m where there is a demand for heavy freight transport.

New lines and replaced bridges are being planned for 10 tons/m, see figure 9.3.
9.9 General loading gauge

Sweden began in 1999 to clear existing lines for the larger loading gauge C where there is a demand for bulky freight shipments. So far, the larger C gauge is used mainly by the forest industry, having built fleets of new containers and wagons for paper and log loading which exceed the A gauge. Track spacing on double track lines varies from 4.1 m to 4.5 m. The obstacles to be cleared for the enlarged gauge are mostly platform roofs and in some cases tunnels, which must be trimmed to clear the top corners. A few lines are cleared for 3.77 m wide wagons carrying packaged lumber three wide instead of two wide.

9.10 Intermodal loading gauge

For intermodal units such as trailers, the intermodal gauge defines the maximum height in cm of a 2.60 m wide trailer, measured from the 0.33 m floor height of a UIC standard pocket wagon [30]. The mainlines connecting Scandinavia and Germany accommodate the loading gauges and intermodal gauges shown below:

- Sweden: Halmstad-Malmö being raised to P/C 450 by 2015, measurements needed to verify extended clearances on several lines;
- Øresund: P/C 450 from 2011;
- Denmark: København-Køge-Ringsted not announced;
- In Norway new lines since 1990 are designed for the UIC GC reference profile.

The increased height is potentially of use also to intermodal shipments as the C gauge can accommodate highway trailers 4.50 m tall, which are common in Sweden and Norway. The increased width is benefitted from not only by freight but also by passenger trains built 3.45 m wide and seating five passengers across, with special permission even on lines with the smaller A gauge, which is 4.65 m high and 3.40 m wide.
9.11 Train length

Several developments are under way to increase train lengths. In Sweden, TRV’s intent is to raise the permissible train lengths with respect to sidings from around 630 m to 750 m on main lines. In Norway, similarly, JBV intends to raise the permissible train lengths with respect to sidings to 750 m on the two main lines connecting with southern Sweden, i.e. Østfoldbanen and Kongsvingerbanen.\(^2\)

It would be desirable to increase train lengths further, and for national limitations to be aligned in corridors where there is a demand for through trains, such as applying the Danish and German limit of 835 m also to connecting lines in Sweden, initially to Hallsberg, which originates daily through trains to Hamburg. To do this further investigation need to be done in Sweden.

Extending the length of trains effectively raises the payload per train, regardless of the commodities carried. Extended train length can be accomplished with point improvements such as constructing longer yard tracks and sidings. Maximum freight train speed and train length (with air brakes) are generally limited by braking performance, load and required stopping distance. Characteristics are as follows:

- Norway: Sidings being extended to 750 m or more between Oslo and Kornsjø and between Oslo and Charlottenberg;
- Sweden: Sidings being extended to 750 m or more when new lines and siding are built
- Øresund: train length 1000 m from 2011
- Denmark: Sidings on the single-track sections between Kolding and Padborg already exceed 930 m.
- Germany: 835 m between Padborg and Hamburg from 2012, many sidings here recently extended to handle 835 m trains. Elsewhere, sidings being extended to handle 750 m trains.

The longer trains in Denmark are facilitated in part by the longer distance between distant signal and home signal, 1200 m on mainlines. In contrast, this distance is generally 1000 m on Swedish and German mainlines. To enable the increase to 835 m length between Padborg and Hamburg, braking performance is discounted and heavy wagons are precluded from long consists.

Aligning national brake rules and tables would also reduce the need to stop and manually re-set wagon brake control valves at the borders or in some cases to reduce train speeds due to differences in the brake tables. This is an important area for further investigation.
9.12 Train mass

It is suggested for the short term to raise the train mass limit for the Copenhagen-Padborg route to the same value as presently in effect across Öresund and in Germany, i.e. 4000 tons.

For the longer term a higher mass limit than 4000 tons should be investigated for the Fehmarnbelt route in light of its lower planned gradient, not to exceed 12.5 ‰.

One way to adapt heavy train operations to the different ruling gradients in southern Sweden of generally 10 ‰ and those of the Öresund link of 15.4 ‰ westbound (in the Drogden tunnel) and 15.6 ‰ eastbound (on the bridge) but generally less than 12.5 ‰ in Denmark except Store Bælt would be to maximise the train mass for double locomotives in Sweden, add a third locomotive to cross Öresund, then continue with double locomotives through Denmark and into Germany, without having to change the wagon consist. To get the highest utility of this scenario, the ruling gradient of the Fehmarnbelt fixed link and its connecting lines should correspond to that of southern Sweden, i.e. not exceed 10 ‰.

There is also a possibility of operating trains heavier than 4000 tons across Öresund westbound if a freight bypass between Peberholm and Kastrup is built not to exceed 12.5 ‰ gradient.

No more than two locomotives should be used on the head end, to avoid couplers breaking. Note that the minimum breaking strength of a standard screw coupler at 850 kN (EN 15566:2009) is significantly higher than the tractive effort of two four-axle locomotives, each at 300 kN.

9.13 Ferry Links

There have been plans to move the ferries to Poland from Ystad to Trelleborg but no decision has been taken.
10 Conclusions and proposals

10.1 Remaining bottlenecks and weak links

Although the existing capacity bottlenecks are being addressed in part by ongoing improvement programs, new bottlenecks will occur as transport demand increases. Significant discrepancies in technical standards exist, which are not yet addressed in infrastructure or operating plans.

In particular, the following bottlenecks and weak links are identified, which hamper the efficient through operation of whole trains or even individual wagonloads in the corridor:

- Finland: partial single track, partially low axle load, no through operation of trains due to wider track gauge.
- Norway: extensive single track, short train length, steep gradient at Halden and Oslo, low and tapered loading gauge, low intermodal gauge.
- Sweden: partial single track, short train length, partially low and tapered loading gauge, partially low intermodal gauge, partially low meter load, partially low axle load.
- Denmark: steep gradient at Storebælt, low, narrow and tapered loading gauge, low intermodal gauge for transit purposes, low meter load on lines connecting Fehmarnbelt, low axle load.
- Germany: non-electrified and single track from Lübeck southward and eastward, no connecting track at Bad Kleinen, narrow and tapered loading gauge, low intermodal gauge for transit purposes (Scandinavia-France), low axle load on most lines.

After completing the West Coast Main Line in Sweden with double track Öxnered-Gothenburg in 2012 and Halmstad-Ångelholm (Hallandsåsen) in 2015, double track also between Haug and Halden will become urgent, after which the line from Halden to Öxnered will be the weakest link between Oslo and Copenhagen.

After completing the Fixed link via Fehmarn Belt in 2021 there will still be some weak links especially in Germany. There is a need for a coordinated plan for upgrade infrastructure for longer freight trains and faster passenger trains. In the long term real high speed lines will free capacity for freight on the conventional lines.

10.2 Conclusions and recommendations

The market share of freight trains in the corridor between Scandinavia and Germany is significantly less than those of trucks and ships. Thus, there is potential for significantly increased transport volumes by train, if the train services are made more attractive to the shipper. The measures outlined here would aim to raise system capacity as well as to lower costs.

Deregulation of freight rail system

In general the deregulation of the freight railway is important to get a more effective and attractive supply for the customers. This is a general measure which has not been especially studied in this project but have to be mentioned.

- The deregulation must be introduced in practice in all countries with no bureaucratic obstacles
- The operators must offer a better service quality and the customer must adopt their logistic systems to more freight by rail
The operators must invest in interoperability
The infrastructure holders must cooperate to offer a freight network for longer and heavier trains, higher meter loads and axle loads, a larger loading gauge and unified brake rules

Measures to develop international passenger rail

The supply of international passenger traffic in the Scandria corridor has decreased in recent decades as a consequence of the deregulation of airlines and much cheaper travels and higher car ownership and investments in better roads. The railways have not so far been able to meet the competition. In short term there is a need for the following measures:

- An information systems and tickets sales for all operators must be available on internet
- Better coordination of time-tables between operators
- More direct connections without change of trains
- Cheap offers is important for leisure travels

In long term there is a need for high speed connections with shorter travel times between the most important towns in the Scandria corridor - less than 3-4h is necessary to compete with airplanes for business travels.

Improving network capacity and quality

Capacity constraints in the form of single track sections exist on several of the lines in the Scandinavian-German corridor. It would be desirable to accelerate track duplication to improve both capacity and fluidity on these lines. In the short term, construction of additional sidings would add capacity and flexibility, particularly near Kornsjø and Ängelholm-Arlöv.

To minimise bottlenecks in northern Germany, existing lines connecting the Fehmarnbelt link to the main north-south corridors through Lüneburg and via Bad Kleinen through Ludwigslust need to be electrified to enable through operation.

Large differences in speed reduce capacity, creating a need for additional sidings even on double track. Additional freight train paths for 120 km/h can be established during daytime in areas where passenger traffic dominates. The number of wagons approved for 120 km/h operation, empty or loaded, is growing steadily, making this feasible.
Adapting technical standards

Significant discrepancies of technical standards still exist between the various national railway networks.

For new construction and upgrading of infrastructure, the opportunity to apply bold, forward-looking standards should be seized. These standards should be as high as, or higher than, the highest existing or planned standards on the connecting corridors and networks.

Increasing train lengths to 835 m appears feasible in the short term between the gateways of southern Sweden and its major marshalling yards: Malmö, Hallsberg, Sävenäs (Gothenburg) and Borlänge as well as Stockholm. This would raise the capacity of run-through trains. The necessary investment could be kept to a minimum, particularly if the longer trains were operated at night, with few fast trains needing to pass and therefore moderate need for extended sidings on the double track lines. In the longer term, increasing train lengths to approximately 1670 m (two long trains coupled) on the main corridors of Germany and Scandinavia appears feasible.
Establishing a large, rectangular loading gauge for new construction and upgrading of existing railway lines. Considering the normal catenary heights of 5.3 to 5.5 m in Denmark and Germany, a height matching the Swedish C loading gauge at 4.83 m appears feasible. A corridor cleared for intermodal loads up to this height between Sweden and France through Denmark and western Germany would be able to transport semitrailers of 4.5 m height, as are common in Norway, Sweden, France and Britain (and Ireland). It would also enable ro-ro loading of 4.0 m high semitrailers onto low-floor flat wagons, thus not limiting intermodal service to only reinforced semitrailers. The forest industry would gain efficiency by being able to load standard lumber packages three high, and by also shipping 3.56 m (140") paper rolls by rail. Thus, a rectangular loading gauge will enable trains of forest products to be loaded to higher meter loads than presently, and to benefit from tandem operation.

Building foundations as well as track for 25 tons axle load or heavier for new construction and upgrading of existing railway lines. 25 tons or heavier is already being applied on portions of several national railway networks in Europe, including those of Finland, Germany, the Netherlands, Norway, Sweden and the United Kingdom.

Raising meter loads to 8.3 tons/m between the gateways of southern Sweden and connecting lines at Halmstad and Hallsberg, in combination with 25 tons axle load.

The 25 ‰ grade at Halden, being twice as steep as other grades on the Oslo-Gothenburg line, restricts train mass on this line. Easing this grade to 12 ‰ would enable heavier trains or eliminate the need for multiple or pushing locomotives, particularly as sidings are being extended on this line.

For reference, similar standards have also been proposed by the Ferrmed Association [38].

The network statement for the Öresund bridge from 2011-12-11 is stated as:

- Axle load 25 tons
- Meter load 8.3 tons/meter
- Intermodal gauge P/C 450
- Train length 1000 m
- Train mass 4000 tons

In the network statement it is also declared that the Swedish loading gauge C 3.60 m×4.83 m will be implemented from 2020, subject to removal of isolated obstacles.

This is a very god example of already built infrastructure which after some supplementary investigations has been proved to fulfill very high performance. The treaty on the construction of the Fehmarn Belt fixed link specifies that it be dimensioned and equipped such that traffic using the Öresund fixed link also be able to use the Fehmarn Belt fixed link (Reference: Traktat mellem Kongeriget Danmark og Forbundsrepublikken Tyskland om en fast forbindelse over Femern Bælt, København, 2008-09-03).
Figure 10.2 Proposed corridor for trailer transport and high loads “Fran-Scan” with P/C 450 gauge between Scandinavia and Britain [7].

Figure 10.2 Proposed loading and intermodal gauges.
10.3 Proposed standard for new links, including Fehmarnbelt and connections

Our proposal is that the planned Fehmarnbelt traverse and its connecting lines including the upgraded or new Storstrømmen bridge should generally match or surpass the highest of German, Danish and southern Swedish standards:

- Maximum speed 250 km/h or higher for passenger trains
- Maximum gradient 12.5 ‰, but preferably 10 ‰. Although Fehmarnbelt is connected in series with the existing Öresund connection which has 15.6 ‰ gradient eastbound and 12.4 ‰ westbound on the bridge portion, a new, parallel freight bypass west of Peberholm is being proposed.
- Length of sidings for 835 m trains plus a portion of the stopping distance, e.g. 835 m + 180 m = 1015 m, but land reserved for 1900 m.
- Distant signals at 1200 m or farther.
- Loading gauge matching the Swedish C profile of 4.83 m × 3.6 m, or reduced to 4.83 m × 3,15 m, with full width at the top.
- Axle load 25 tons or higher.
- Meter load 8,3 tons/m or higher.
- Train mass up to 5200 tons on 10 ‰, 4200 tons on 12.5 ‰, or heavier, depending on locomotive configuration.

This will make the rail system much more competitive in the future also to fulfil the targets of EU for a sustainable transport system.
10.4 Investments beyond present infrastructure plans

Infrastructure improvements

The purpose of these development priorities is to be published as part of the final Scandria Project Action Program or policy document, in order to influence the next set of strategic infrastructure plans in the Scandria corridor area:

- Finland: transport network investment beyond 2020
- Norway: National Transport Plan 2014-2023
- Sweden: supplementary infrastructure bill 2012-2025
- Denmark: political agreements
- Germany: Federal Transport Infrastructure Plan 2016-2030

Thus, the improvement priorities included reflect the needs for the period 2012-2030 (approximately).

With the overall aims of enabling efficient, reliable and sustainable passenger and freight transportation meeting the needs of passengers and shippers, while accommodating mode shift in accordance with the goals of the EU, and based on review of

- transportation trends and forecasts
- present transportation system performance and standards
- present national infrastructure plans

The Scandria Project (WP 3.2) has identified the following needs for railway improvement beyond the present national transportation infrastructure plans, which should be investigated with high priority for inclusion in the plans. A proposal for further investigations is shown in table 10.1.

Recommended best common practice

In table 10.2 is shown a recommended best common practice to be used for upgraded or new railway links. It is based largely on the best standards in use today in the Scandria corridor, and aims to enable the main transportation flows in the corridor to follow one common standard. It corresponds closely to the standards in effect on the existing Øresund link, hence the name “Øresund standards”.

### Table 10.1 Proposal of infrastructure investments beyond present infrastructure plans.

<table>
<thead>
<tr>
<th>Description</th>
<th>Time horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kokkola – Seinäjoki, Pohjois-Louko – Lielahiti: extension of double track</td>
<td>≈ 2030</td>
</tr>
<tr>
<td>Haug – Halden: double track</td>
<td>≈ 2025</td>
</tr>
<tr>
<td>Sarpsborg – Skånebol: loading gauge SE-C; intermodal gauge P/C 450</td>
<td>≈ 2015</td>
</tr>
<tr>
<td>Järna – Nyköping – Linköping: new link, ≥ 320 km/h</td>
<td>≈ 2025</td>
</tr>
<tr>
<td>Hallsberg – Degerön: completion of double track</td>
<td>≈ 2021</td>
</tr>
<tr>
<td>Ångelholm – Åstorp – Teckomatorp – Kävlinge – Arlöv: additional passing sidings, longer sidings for 835 m trains</td>
<td>By 2015</td>
</tr>
<tr>
<td>Åstorp – Teckomatorp: centralised traffic control</td>
<td>By 2015</td>
</tr>
<tr>
<td>Lund – Flackarp: quadruple track</td>
<td>≈ 2020</td>
</tr>
<tr>
<td>Lockarp – Trelleborg: longer sidings for 880 m trains</td>
<td>By 2015</td>
</tr>
<tr>
<td>Peberholm – Kastrup: freight bypass, ≤ 12 ‰</td>
<td>By 2020</td>
</tr>
<tr>
<td>Köge – Næstved: electrification, upgrade for ≥ 200 km/h</td>
<td>By 2020</td>
</tr>
<tr>
<td>Puttgarden – Lübeck: upgrade for ≥ 200 km/h</td>
<td>By 2020</td>
</tr>
<tr>
<td>Lübeck – Bad Kleinen: electrification, upgrade for ≥ 200 km/h</td>
<td>By 2020</td>
</tr>
<tr>
<td>Bad Kleinen: connecting track (wye) (Bobitz) – (Lübstorf)</td>
<td>By 2020</td>
</tr>
<tr>
<td>Lübeck – Büchen – Lüneburg: electrification, longer sidings for 835 m trains</td>
<td>By 2020</td>
</tr>
</tbody>
</table>

### Table 10.2 Proposal of best common practice.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Recommended best common practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger train speed</td>
<td>≥ 200 km/h (upgraded), ≥ 320 km/h (new)</td>
</tr>
<tr>
<td>Freight train speed</td>
<td>100 km/h (night), 120 km/h (day)</td>
</tr>
<tr>
<td>Freight train length</td>
<td>Single train: 730 m (P), 835 m (5GP), 880 m (G)</td>
</tr>
<tr>
<td></td>
<td>Double train: 1460 m (P), 1670 m (5GP), 1760 m (G)</td>
</tr>
<tr>
<td>Wagon mass on ≤ 10 ‰</td>
<td>Single train: loco+(≈)5200 tons (screw couplers)</td>
</tr>
<tr>
<td></td>
<td>Double train: loco+(≈)5200 tons+loco+(≈)5200 tons (screw couplers)</td>
</tr>
<tr>
<td>Loading gauge</td>
<td>Rectangular (flat top): 3.15 m × 4.83 m, specific links 3.60 m × 4.83 m (SE-C)</td>
</tr>
<tr>
<td>Intermodal gauge</td>
<td>2.60 m × 4.33 m (P/C 400), specific links 2.60 m × 4.83 m (P/C 450)</td>
</tr>
<tr>
<td>Meter load</td>
<td>≥ 8.3 m</td>
</tr>
<tr>
<td>Axle load</td>
<td>≥ 25 tons</td>
</tr>
<tr>
<td>Gradient</td>
<td>≤ 12.5 ‰</td>
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<tr>
<td>Wagon brake ratio</td>
<td>SS ≥ 80 ‰</td>
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### Mode

<table>
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### Frequency (number of trains per weekday and direction)

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*Of which 3 via Rödby-Puttgarden and 7 via Padborg*
## Passenger transport performance

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** From navigation tool at www.maps.google.se
*** With half an hour rest after 3.5 h sailing
**** From navigation tool at www.maps.google.se including distance for ferry
References:


