Rail Freight with the Fehmarn Belt Fixed Link

Forecasts, Challenges and Solutions

2023-03-31

STRING is a political member organisation for local and regional authorities in Northern Europe between Oslo and Hamburg. Major cities and regions in STRING join together to connect and align politically, industrially and geographically to accelerate the green transition and unlock new potential for green growth and sustainable transport infrastructure.

Greater Copenhagen is a collaborative organization promoting growth and development in the largest Nordic metropolitan area, encompassing 4.4 million citizens in Southern Sweden and Eastern Denmark.

Sweco is Europe's leading architecture and engineering consultancy.

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Foreword

Greater Copenhagen and STRING both operate with the same purpose – ultimately assuring a better quality of life for the inhabitants in our regions.

Greater Copenhagen is a Danish-Swedish political co-operation between southern Sweden and Zealand in Denmark, building one of the world's most competitive metropolitan regions by improving infrastructure and integrating the regional cross-border labour market. STRING represents local and regional northern European authorities from Oslo to Hamburg in a *megaregion* – a combination of cities and regions, spanning national borders, considered the natural units and engines of the global economy. A driving idea behind the metropolitan area as well as the megaregion is to harness the benefits of agglomeration economies by increasing sustainable connectivity and interconnectedness.

Both organisations consider the construction of the Fehmarn belt Fixed Link (FBFL) one of the most important projects Europe has seen since the inauguration of the Öresund bridge. It will have far-reaching economic impacts – for creating a cohesive labour market, for our potential to market ourselves as an international green hub, for transport connectivity, and for meeting EU transport targets.

The reason for commissioning the report that you are about to read was for our organisations to understand how the FBFL can facilitate a modal shift from road to rail to help meet the EU targets and the green development of our regions. To do this, we need to understand future possible rail freight volumes across the FBFL – and identify what might potentially hinder a modal shift from road to rail; and finally, how to overcome such potential challenges. This report is one-step in that direction – the next being a political discussion on how to move forward with these recommendations.

Over the last decades, rail has lost market shares to road, which has generally responded better to the demand for reliable and flexible logistics with short transport times. This will continue to be the case also after the FBFL, as bottlenecks and capacity restraints severely affects every factor of competition. In short, – the FBFL can be a real game changer for assuring a modal shift from road to rail – but this requires action.

Whilst traffic flows in general will likely see substantial effects, the scope of this report has been limited to exploring the potential for modal shift from road to rail; as this is where the potential for more sustainable transport methods are as rail is an energy-efficient and environmentally-friendly way to transport goods. However, we need to take action for this to happen. Therefore, specific and actionable recommendations, for policy-makers, businesses and other stakeholders conclude the report and set the stage for action, discussion and execution going forward.

The FBFL can be an unprecedented game changer in supporting a low-carbon transition, increase labour mobility throughout the megaregion, and strengthen cross-border innovation. But we must acknowledge and solve the remaining challenges to leverage the FBFL and maximise this incredibly opportunity.

We hope you enjoy the report, and that it ignites an understanding of what still needs to be done – together.

Thomas Becker

Managing Director
STRING

Tue David Bak

Managing Director
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Summary

Executive summary

The Fehmarn Belt Fixed Link (FBFL) will remove a key bottleneck between Scandinavia and Germany, hereby reducing transport times and costs, contributing to efficient logistics in the transport corridor. This could be an opportunity to realize the potential for more rail transport.

However, for such a development to happen, the FBFL must be supported with other measures increasing rail transport attractiveness. During the last decade, road transport across the Fehmarn Belt has grown at least three times faster than rail transport. Depending on the period studied, rail transport has even had negative growth, while road freight growth rates have been stable. This is not unique for the STRING corridor, but a pattern that is to some extent repeated all over Europe and over the last decades. Rail freight transport is struggling to meet the demand structure for modern logistics, including reliability of service, transport time, transport costs and flexibility.

In the scenarios in the report, rail freight volumes are expected to increase with about 20 % or less until 2040. It cannot be ruled out that volumes would even decrease. Meanwhile, road freight across the Fehmarn Belt is expected to increase at least by 50 % and it might double.

In the scenarios in the report, rail freight volumes are expected to increase with about 20 % or less until 2040. It cannot be ruled out that volumes would even decrease. Meanwhile, road freight across the Fehmarn Belt is expected to increase at least by 50 % and it might double. Annual rail freight is forecasted to increase from 6.9 million tonnes (37 trains per day) to 8.1 million tonnes (44 trains per day) or less. Annual road transport volumes could increase from 8.5 million tonnes (2 200 trucks per day) to between 12 and 19 million tonnes (3 200 to 4 900 trucks per day). Such a development will lead to serious congestion in the road network, but the effects could be partly remedied by longer/heavier trucks.

There are three main reasons why the FBFL alone will not lead to a significant modal shift from road to rail transport. Firstly, the FBFL improves road transport attractiveness as well, albeit not as much. Secondly, in transport chains lasting 24 to 48 hours, the time saving of 2.5 hours equals a reduction of 5-10 % and about as much for transport costs. Although being a significant reduction, it might not be enough for altering the competitiveness and attracting much road freight volumes.

The third reason is capacity constraints in other parts of the railway network within and adjacent to the STRING corridor. Capacity constraints affect all factors important to the choice of transport mode, hence impeding the benefits of the FBFL. The FBFL and its connections will be one strong link in a chain with many weak links.

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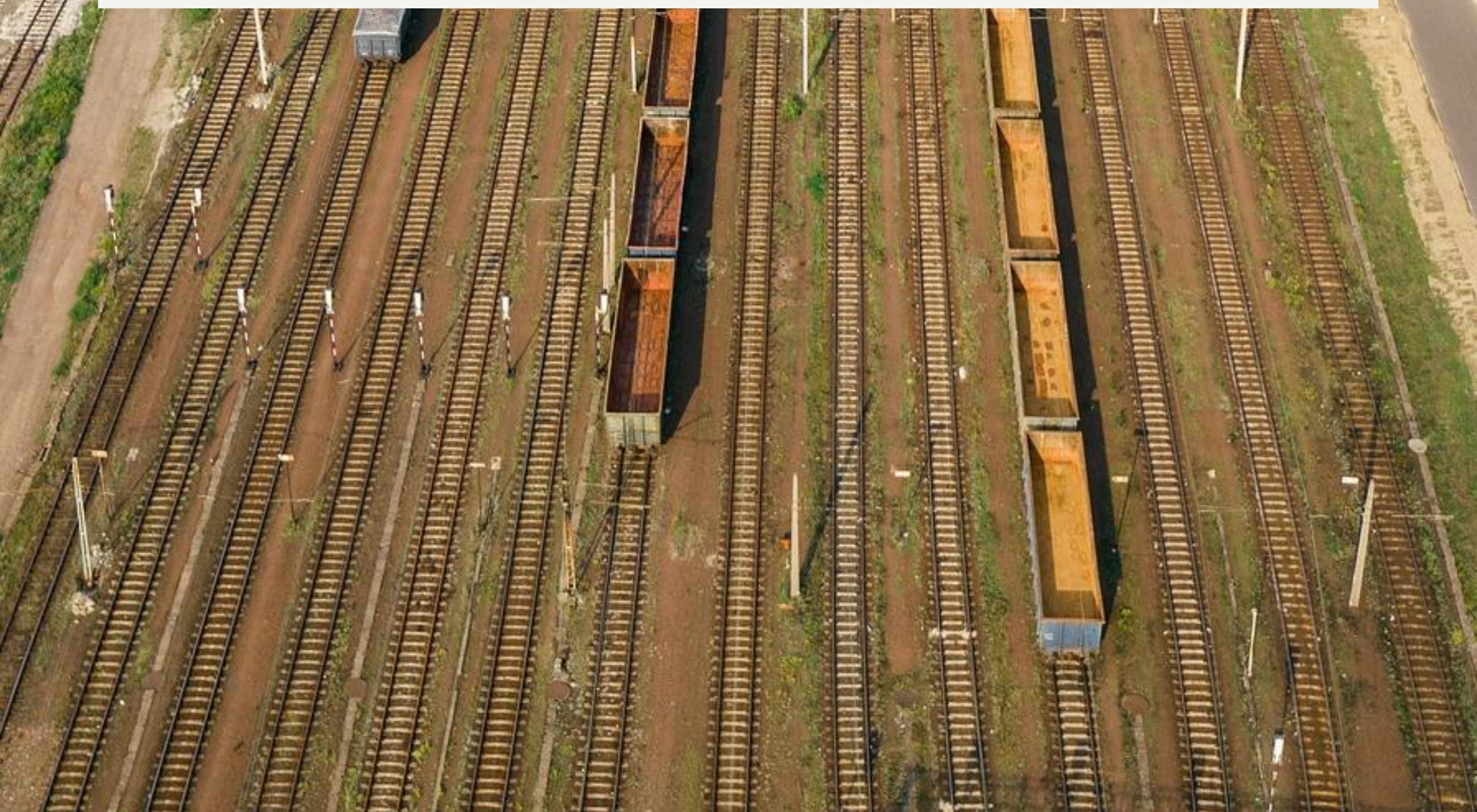
Complementary initiatives are needed to enable a modal shift and to utilize the FBFL:

- Remove infrastructure bottlenecks and capacity constraints within the STRING corridor and in the adjoining railway network.
- Enable full train lengths (740 metres or longer) to increase cost efficiency and possibly reduce capacity constraints.
- Ensure faster trains (120 km/h or more) to shorten transport times, enlarge the catchment area and better utilize railway capacity.
- Ensure competition between or within intermodal terminals in Denmark, contributing to cost efficiency, increased reliability, and capacity.
- Ensure that all transport modes pay for their negative effects on the environment, infrastructure maintenance, congestion, and traffic safety, among others.
- Provide the necessary infrastructure for zero or low-emission fuels for road transport, a crucial factor to minimize greenhouse gas emissions.



Background

The STRING transport corridor connects Hamburg and Oslo via Copenhagen, Malmö, and Gothenburg. The region is an essential part of the Scandinavian-Mediterranean transport freight corridor with 14 million inhabitants and many leading industries and important transport nodes.

The STRING geography has massive economic activities, particularly concentrated in and around Hamburg, Lübeck, Copenhagen, Malmö, Helsingborg, Halmstad, Göteborg and Oslo. Such a concentration along a single corridor is potentially favourable for the demand of rail transport and could ensure large volumes and hence high efficiency, economically as well as environmentally. However, the market share for rail freight is currently low, and the efficiency and costs of the rail services not sufficiently competitive.

The Fehmarn Belt Fixed Link (FBFL) will remove a bottleneck and reduce transport times, contributing to efficient logistics between Scandinavia and Continental Europe.

The tunnel under the Fehmarn Belt between Denmark and Germany is planned to open in 2029. The Fehmarn Belt Fixed Link (FBFL) will remove a bottleneck and reduce transport times, contributing to efficient logistics between Scandinavia and Continental Europe. This could be an opportunity to realize the potential for more rail transport.

However, it is crucial to ensure the railway's capacity to avoid a situation where passenger trains and freight trains compete for time slots on the tracks. Capacity constraints and bottlenecks could effectively limit the potential positive impacts of rail transport.

It is also important to take complementary measures to increase the competitiveness of rail transport, for example by enabling a higher degree of competition between service providers and allowing longer and faster trains.

Purpose of this study

The purpose of this study is hence threefold:

- To describe possible future rail freight volumes across the FBFL in the years 2030. 2035 and 2040.
- To identify infrastructure problems and other obstacles or barriers that must be solved to fully utilize the FBFL and increase railway competitiveness.
- To propose solutions on how to overcome the challenges identified in step 2, thereby closing the gap between forecasts and EU targets.

Focus of the study is rail freight transport, reflecting the political ambition to transfer cargo from road to rail as well as the challenges for achieving this. Still, road transport is discussed extensively and scenarios for future road freight volumes are also included.

The study has combined quantitative data with qualitative assessments, addressing the purpose from various perspectives.

Development of rail and road

Figure 1 shows rail volumes during the last decade in the four countries in the STRING corridor. Since 2011, Norway and Sweden have experienced a rising demand for rail transport. In Germany, there has been a small decline, while rail volumes in Denmark have fallen during recent years.

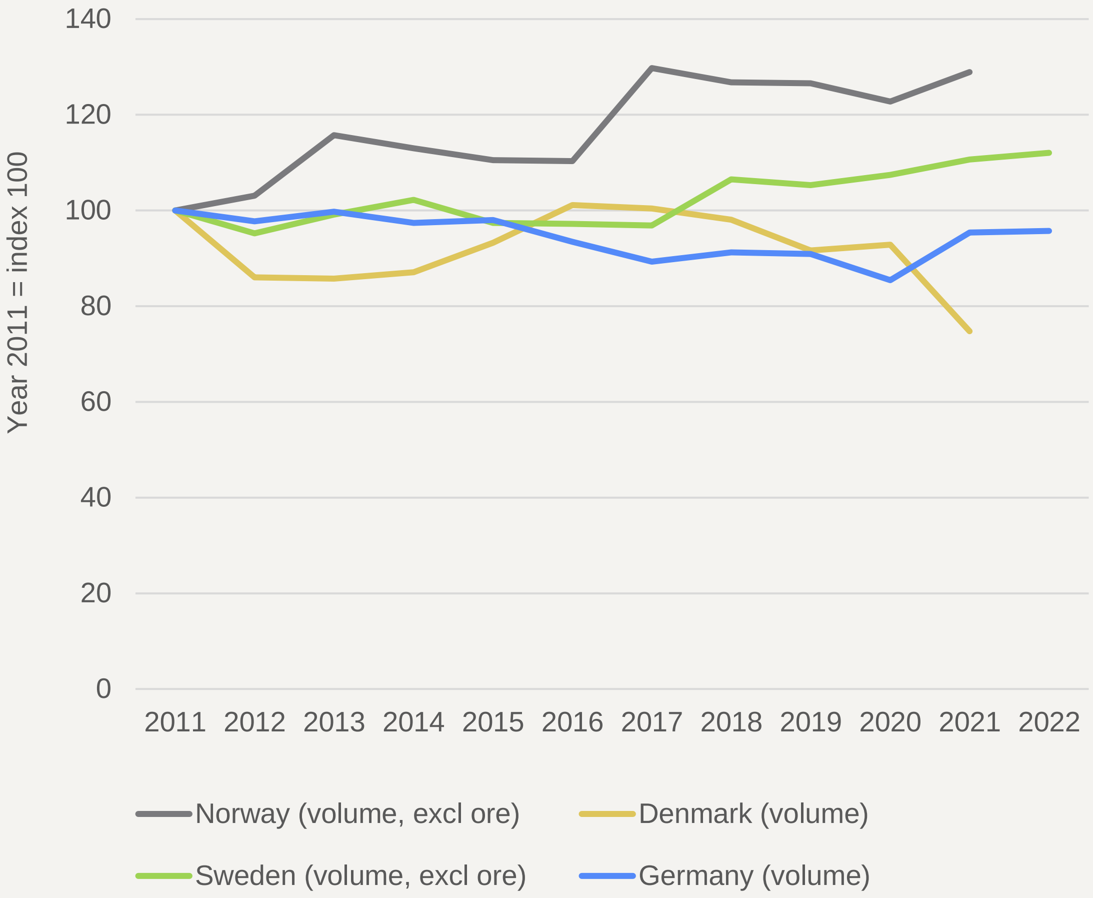


Figure 1. Rail volumes from 2011 (index 100). Both international, domestic and transit transport are included. Sources: Statistisk sentralbyrå Table 10511; Danmarks statistik Table BANE1; Trafikanalys Railway transport 20220 Quarter 4 Table 3; Statistisches Bundesamt Table 46131-0001.

Over the last decades, rail has lost market share to road freight, which has generally responded better to the demand for reliable and flexible logistics with short transport times. It is difficult to draw unambiguous conclusions from different market drivers, but some tendencies together create an opportunity for rail freight to develop positively in the coming years. This applies, for example, to rising energy and fuel prices and a

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strong and growing focus on climate considerations, the environment and sustainability in general. However, a potential growth in volumes accentuates the limitations represented by a rail network with serious and increasing capacity constraints.

The latest forecast for the FBFL was performed in 2014 by Intraplan and BVU. According to the forecast, existing rail freight volumes through and to/from Denmark or via ferries between Southern Sweden and Germany will make up 98 % of the volumes on the FBFL. Only 2 % additional volumes will transfer from road transport. The general conclusion is confirmed by other transport models (TØI and SITMA AS 2019; Sweco 2023a) and by case studies (Atkins, Trafik- Bolig- og Byggestyrelsen 2020; Sweco 2023c). Although the FBFL will reduce transport times with about 2.5 hours for rail, this is a rather marginal effect. In transport chains being 24-48 hours long, it equals a relative saving of about 5-10 %. A similar effect is found when looking at transport costs, although there are examples when the effects can be larger. It could be noted that road transport will benefit from about 1 hour reduced transport time.

The forecast from 2014 lowered expectations of transport development relative to the previous prognosis from 2002 (Intraplan and BVU 2014). The actual development until today has been even weaker than the main scenario from the forecast from 2014 though, resulting in a “deficit” of about 1.3 million tonnes per year. This equals seven freight trains per day.[1]

Road freight volumes on the ferry lines Rödby-Puttgarden and Gedser-Rostock have increased by 45 % between 2011 and 2021, resulting in an annual growth rate of 3.4 %. Close to 92 % of future road freight volumes on the FBFL will come from the existing ferry line Rödby-Puttgarden.

Road freight volumes on the ferry lines Rödby-Puttgarden and Gedser-Rostock have increased by 45 % between 2011 and 2021, resulting in an annual growth rate of 3.4 %. Close to 92 % of future road freight volumes on the FBFL will come from the existing ferry line Rödby-Puttgarden (Intraplan and BVU 2014 p.153). Current road freight volumes on that ferry line are about 9 million tonnes today (Danmarks statistik 2023 Table SKIB32), clearly surpassing the forecast for 2025 of 6.9 million tonnes after the opening of the FBFL (Intraplan and BVU 2014 p.165).

Scenarios for future freight transport on the FBFL

Six scenarios are used to illustrate possible future developments until 2040 (Table 1). Four cover rail transport and two road transport. Since the modal shift from road freight to rail because of the FBFL is expected to be very small, the scenarios could very well co-exist, as they depend more on the development of trade volumes than on each other.

[1] Using an average weight of a freight train of 724 tonnes (Trafikstyrelsen 2023 p.15) and 255 operating days per year (Intraplan and BVU 2014). About 30 freight trains cross the Öresund Fixed Link each day (Öresundsbrokonsortiet/Trafikverket 2022).

Table 1. Six scenarios for future rail and road volumes on the Fehmarn Belt Fixed Link.

Scenario	Description	Purpose
Rail: Average of National Forecasts	Calculation of an average of national forecasts, weighted by the most important rail freight relations, based on volumes. The growth rate is applied on current land-based rail volumes. The volumes on the railway ferries are assumed to transfer to land and form a part of the growth for the land-based volumes.	This scenario makes use of national forecasts, considering for instance prognoses of demography, economic development, and trade. The scenario illustrates a development with growing rail volumes.
Rail: History High	Linear projection of the historical development 2010-2021, combined with effects of the FBFL according to the 2014 forecast (Intraplan and BVU 2014).	This scenario illustrates a development with growing rail volumes.
Rail: History Low	Linear projection of the historical development 2012-2021, combined with effects of the FBFL according to the 2014 forecast (Intraplan and BVU 2014).	This scenario illustrates a development with declining rail volumes.
Rail: Weak Competitiveness	Projection of the historical development 2010-2021 based on a more advanced mathematical trend analysis, combined with effects of the FBFL according to the 2014 forecast (Intraplan and BVU 2014).	This scenario illustrates a development with severely declining rail volumes, a “worst case” for the railway.
Road History	Linear projection of the historical development 2010-2021, combined with effects of the FBFL according to the 2014 forecast (Intraplan and BVU 2014 p.153)	This scenario illustrates a strong development of road freight transport.
Road Low	Calculation of a simple average of national forecasts in the STRING countries.	This scenario is included to show a much weaker development of road freight than the last decade, albeit also leading to increased volumes.

An underlying assumption for all scenarios is that population, economic growth, and trade will have a positive development in the STRING countries during the period, although there will surely be recessions as well. The assumption is supported by national forecasts as well as prognoses from organizations like OECD (ITF/OECD 2021).

EU targets are used as a benchmark for rail freight volumes. Rail freight transport should increase by 50% by 2030 and by 100 % by 2050 compared to 2015 (EC 2020a, p.11). The rail freight scenarios and EU targets are shown in Figure 2. Clearly, EU targets are much above even the most optimistic forecast of future rail freight volumes.

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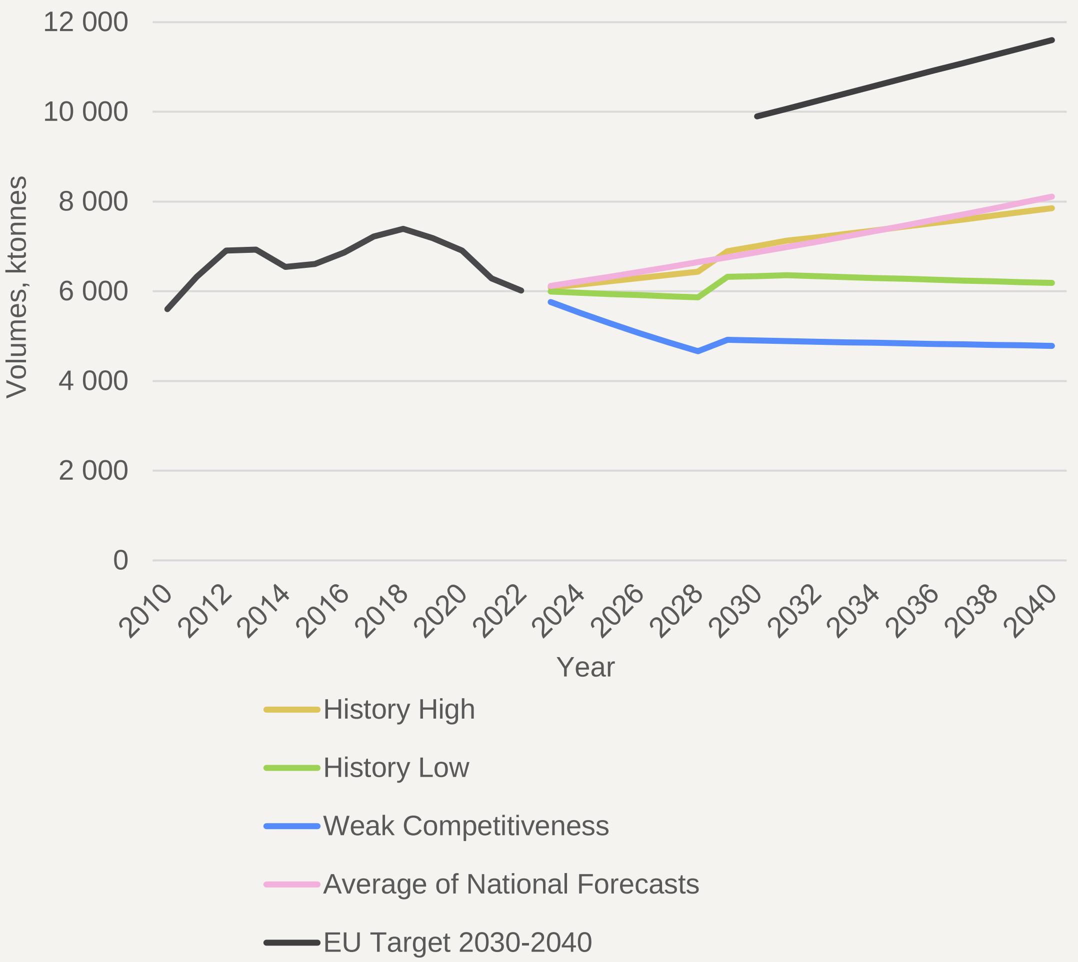

Figure 2. Four scenarios for railway volumes on the FBFL and the EU targets as a benchmark. Sources: Actual volumes: Danmarks statistik 2023 Bane1; Trafikanalys (2023) Sjötrafik; forecasts: Sweco

The four rail freight scenarios are presented in Table 2. In the table, the figure 6.9 million tonnes for volumes in 2022 is used, including current rail transport on land as well as rail freight volumes on railway ferries between the Southern part of Sweden and Germany.

Table 2. Four scenarios for rail freight volumes on the FBFL.

Scenario	Volumes/trains[2]	Year				Change
		2022	2030	2035	2040	2022-2040
Average of National Forecasts	Volumes (Mtonnes/year)	6.9	6.9	7.5	8.1	18 %
	Trains per day	37	37	40	44	
History High	Volumes (Mtonnes/year)	6.9	7.3	7.7	8.1	18 %
	Trains per day	37	39	42	44	
History Low	Volumes (Mtonnes/year)	6.9	6.3	6.3	6.2	-10 %
	Trains per day	37	34	34	34	
Weak Competitive-ness	Volumes (Mtonnes/year)	6.9	4.9	4.8	4.8	- 30 %
	Trains per day	37	27	26	26	

Scenario History High is similar to the Average of National Forecasts. History Low has a weak development and Weak Competitiveness even more so. Neither History High nor Average of National Forecasts are even close to reaching EU targets, neither is the EU (EC 2022).

[2] The number of trains are calculated by using the average weight of a freight train in Denmark in 2020, 724 tonnes (Trafikstyrelsen 2023 p.15) and 255 operating days per year (Intraplan and BVU 2014).

The two road freight scenarios are presented in Figure 3 and Table 3.

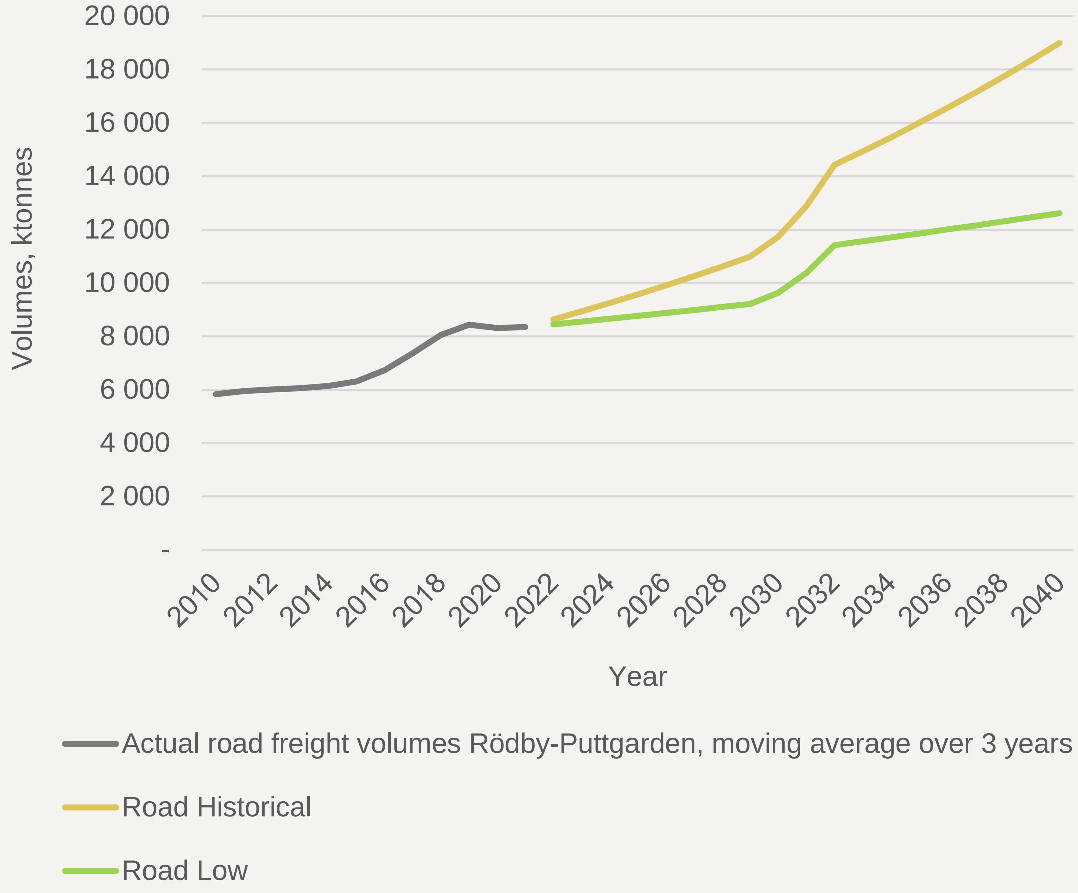

Figure 3. Two scenarios for road freight volumes on the FBFL.

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Scenario	Volumes/trucks[3]	Year				Change
		2022	2030	2035	2040	2022-2040
Road History	Volumes (Mtonnes/year)	8.5	11.7	16.0	19.0	+120 %
	Trucks per day	2 200	3 000	4 100	4 900	
Road Low	Volumes (Mtonnes/year)	8.5	9.6	11.9	12.6	+ 49 %
	Trucks per day	2 200	2 500	3 000	3 200	

Both Road History and Road Low lead to a much larger increase of volumes than even the most favourable rail freight scenarios. Road freight is expected to increase

[3] The number of trucks is calculated by using the average load for trucks of about 15,3 tonnes and 255 operating days per year (Intraplan and BVU 2014).

by between four and eleven million tonnes until 2040. The large difference reflects uncertainties regarding future transport volumes in total, rather than possible modal shifts. Meanwhile, rail freight volumes are expected to increase by 1.2 million tonnes or less.

Some market trends and drivers are favourable for rail transport until around 2030, when road transport is expected to have partly caught up with the competitive advantage of freight trains in the form of energy efficiency and relatively low climate impact. The following aspects favour rail freight or restrict road transport:

- Energy and fuel prices are expected to increase. This will favour rail, which is more energy efficient.
- Increased focus on environmental sustainability should favour rail freight, thanks to superior energy efficiency. When the needed electricity is produced without greenhouse gas emissions, climate performance is enhanced even more.
- Limited access to truckdrivers. Because of new EU regulations, the access to truck drivers is expected to decrease, which could restrict capacity and increase wages.
- Introduction of road tolls for trucks in Denmark from 2025.

Increased focus on environmental sustainability should favour rail freight, thanks to superior energy efficiency.

There are, however, factors that favour road transport or disfavour railway transport:

- Capacity constraints. This is a challenge for road as well, but it is more troublesome for rail. The situation is most serious in Germany, where the government has launched a "first aid for the railways" (BMVDb 2022). In Denmark, the decided infrastructure plan should take care of most bottlenecks during the coming ten to twelve years. In Sweden and Norway, no current plans seem to address the major capacity constraints.
- Limited access to rail infrastructure, as more and more industrial side tracks are shut down. Also, there are many examples of companies moving from locations with access to side tracks to new locations along the motorway system. Both trends mean that rail access is only feasible via a pre-haulage to a terminal.
- Too few railway terminals and limited competition within and between terminals, particularly in Denmark, limits the use of multi-modal transport.
- Rail service constraints in the form of scheduled services with limited capacity between dedicated origins and destinations.
- Technical restrictions of train lengths, particularly in Sweden and Norway, restrictions on maximum speed and requirement of locomotives with multiple signalling systems all add to higher costs for capital and operations. Cross-border transport by rail is also much more demanding compared to road transport regarding legislation and rules, adding costs for administration (Rail Freight Forward Coalition 2018).

- Access to train drivers. This is a serious challenge in Sweden as well as in Germany (Järnvägar.nu 2023a).

A modest rail transport growth is supported by for instance the latest German forecast where rail freight volumes are expected to grow by 0.4 % per year until 2051 (Intraplan and TTS Trimode 2023 p.49) and the annual growth rate on the Öresund Fixed Link between 2010 and 2019, which was 1.0 % (Ramboll and MOE Tetraplan 2020).[4] Transport authorities Trafikverket (2020) and Trafikanalys (2022a) have highlighted the fact that Swedish foreign trade has actually been stable during the last decade, measured in weight.

The major obstacles to a more favourable rail freight development are capacity constraints in the rail network, especially in Germany, in combination with the demand structure for logistics services where rail freight is facing challenges.

In sum, a development somewhere between scenarios History High and Average of National Forecasts and History Low seems plausible for rail transport. The major obstacles to a more favourable rail freight development are capacity constraints in the rail network, especially in Germany, in combination with the demand structure for logistics services where rail freight is facing challenges. Although scenario Weak Competitiveness is not deemed likely, it cannot be ruled out, and serves as a reminder that unless the attractiveness of rail freight is improved, a negative development path may be the result.

The average freight train in Denmark carries 19 % more cargo in 2020 than in 2010 (Trafikstyrelsen 2023 p.15). Should that development continue, the expected growth in the positive scenarios above could be managed by using longer/heavier trains.

During 2017-2021, an average of 32 freight trains per day used the Öresund Fixed Link. Most freight trains across the FBFL will cross the Öresund Fixed Link, which will also be crossed by freight trains to/from Denmark and Sweden/Norway. This indicates a close to 40 % increase of freight trains on the Öresund Fixed Link in the most positive scenarios.

However, the problem is not growth rates, but the fact that the railway does not take a larger share of existing transport volumes. Counting Norwegian and Swedish road transport to and from Continental Europe only, the market is at least 15-17 million tonnes per year.

[4] The number of freight trains on the Öresund Fixed Link has dropped since 2019 (Öresundsbrokonsortiet/Trafikverket 2022).

Regarding road freight, it seems likely that the actual development is somewhere in between the two scenarios. By 2030-2040, depending on the growth rate, the number of trucks could lead to severe congestion problems, especially around the larger metropolitan regions. Growth could also be obstructed by lack of truck drivers. The scenarios do not take into consideration the possibility of longer/heavier trucks but assume that the average weight is per truck is constant.

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Rail competitiveness and the effects of the FBFL

Four factors are central to the competitiveness of transport modes: Reliability of service, Transport time, Transport costs and Flexible logistics.

Results from a transport purchasing panel organized by Chalmers University of Technology, University of Gothenburg and IVL Swedish Environmental Institute (2023) show a development towards demanding better environmental performance, albeit slowly. It is doubtful whether this will increase the market's willingness to pay "extra" for rail transport, while measures that combine environmental gains with reduced costs are attractive.

The FBFL adds strategic and operative **reliability** through Denmark. At the strategic level, there will be two railway lines through Denmark. At the operative level, the fixed link and the connecting, new and upgraded railway lines will reduce disturbances due to infrastructure problems. Still, many challenges remain. Rail transport perform poorly with respect to punctuality in the entire corridor, to a large extent because of capacity constraints and lagging maintenance. In 2021, punctuality for DB Cargo was 73 %[5], a figure that fell to 65 % during the first part of 2022. About 80 % of the disturbances are caused by the infrastructure (BMDV 2022). In the Scan-Med corridor, from January 2018 to June 2019, close to 25 % of all freight trains were more than 6 hours delayed (Cox 2022 figures 10 and 11). Considering this, the time gained from the FBFL will probably often be utilized as a safety margin.

Faster trains would meet long-term logistics trends rewarding shorter transport times. They would play an important role in increasing railway capacity. Faster trains clearly have a large potential to increase the operational area, hence enlarging catchment areas.

The effects of the reduced **transport time** from the FBFL will span from increased safety margins, adding to the reliability, to reduced costs through potential threshold effects. For many logistics chains the effects are relatively limited, but it seems likely that the potential for direct shuttle trains will increase. This adds more time gains as coordination needs with other time schedules are reduced. To increase railway competitiveness, many more initiatives are needed, however.

[5] Defined as a freight train being no more than 16 minutes delayed.

Faster trains would meet long-term logistics trends rewarding shorter transport times. They would play an important role in increasing railway capacity. Faster trains clearly have a large potential to increase the operational area, hence enlarging catchment areas and possibly leading to either or both of the following effects, a) making new freight train lines profitable, b) increasing the profitability of existing rail transport. However, running faster trains on single stretches might not give any advantage if bottlenecks remain, either in the railway network or in intermodal transport chains.

The FBFL will lead to a reduction of **transport costs**. Although the effects vary depending on the transport chain, case studies indicate a 5-10 % cost reduction. In some cases, the benefit could be considerably larger thanks to threshold effects, but the reduction could also be lower. Transport costs could also be reduced through faster trains. Of specific concern is the comparatively high fees for handling units at the Danish intermodal terminals. The potential for longer and heavier trains appears especially large as they reduce fixed costs per tonne moved, improve energy efficiency, and increase network capacity. Although the STRING corridor in general has comparatively favourable conditions for longer trains, there are serious constraints remaining in Sweden and Norway.

The FBFL and connecting, new and improved railways will increase **logistics flexibility** by allowing for more trains and more time slots. Outside rush hours, there will be three hourly time slots for freight trains through Denmark, two via the FBFL, and one via Great Belt Fixed Link (Trafikstyrelsen 2023 p.15).

Capacity constraints obstructing the development of rail freight

However, remaining capacity constraints in other parts of the railway system reduce the benefits of the FBFL. The reason is that bottlenecks, single-tracks, restrictions on train length or weight, speed reductions, steep gradients, lack of terminal capacity and other infrastructure shortcomings have a negative impact on every one of the most important factors when choosing transport mode. These capacity constraints appear in all parts of the STRING corridor as well as in adjacent regions (Figure 4). The major capacity constraints are presented below in two categories:

Bottlenecks, single-tracks, restrictions on train length or weight, speed reductions, steep gradients, lack of terminal capacity and other infrastructure shortcomings have a negative impact on every one of the most important factors when choosing transport mode.

A. Elements already restricting the competitiveness of rail transport

B. Elements that will restrict railway transport competitiveness by 2030

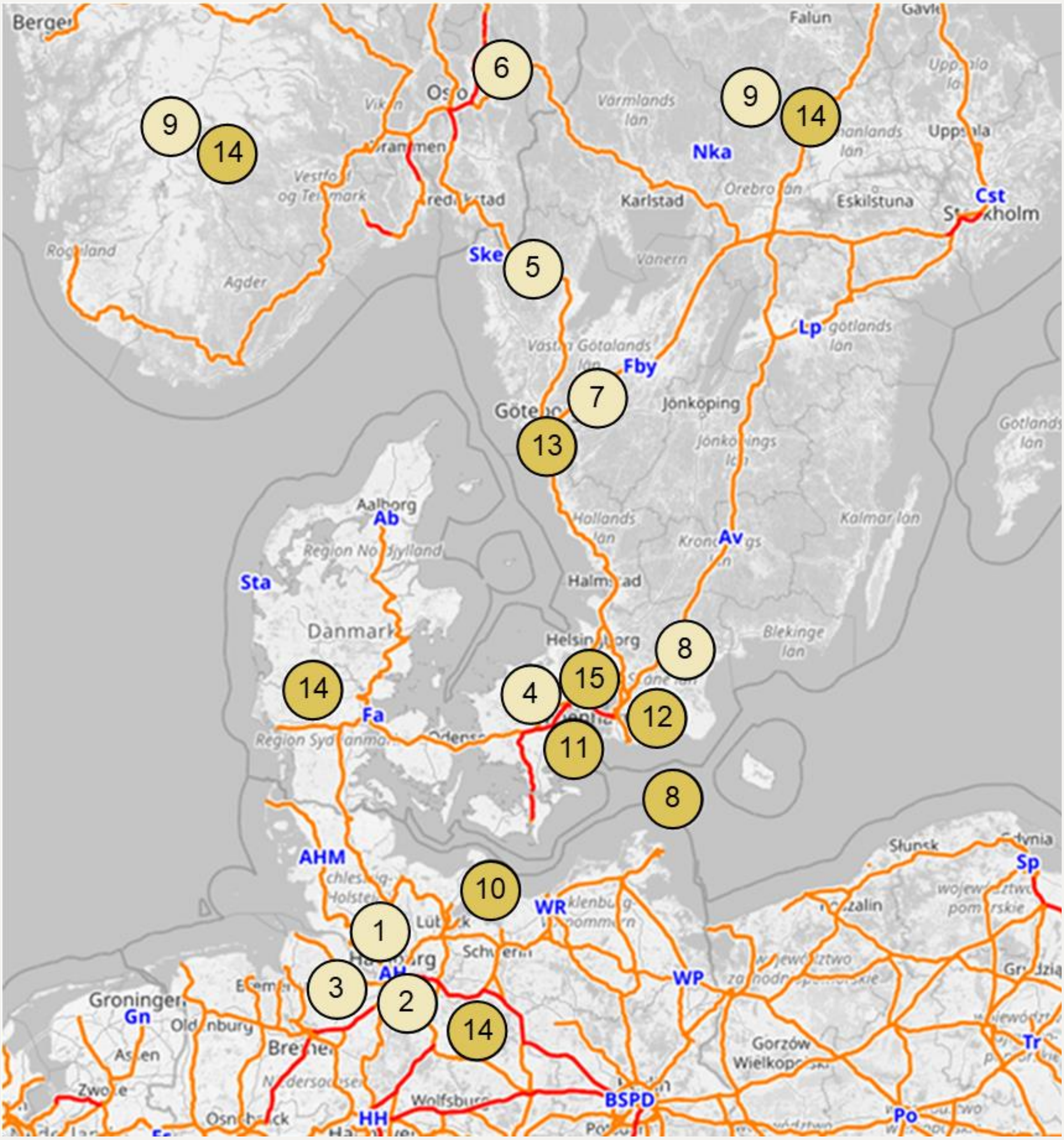

Figure 4. Infrastructure projects that are already obstructing rail transport or will do so by 2030. Map: Open Rail Map, www.openrailmap.org

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Category A

1. Rail node Hamburg. Hamburg is not only a large metropolitan region, but also at the crossroads between three TEN-T corridors; the North Sea-Baltic, the Orient-East Med and the Scandinavian-Mediterranean. It is vital for rail freight in the STRING corridor.

2. The railway Hamburg-Hannover. The railway between Hamburg and Hannover is one of the most utilized transport corridors in Germany with an urgent need to increase capacity.

3. Hamburg terminal capacity. The Port of Hamburg is one of the largest logistics and industrial zones in Germany. Capacity is highly utilized, to the extent where it is causing waiting time as well as complicating logistics.

4. Terminal availability and prices in Denmark. There is a lack of open railway terminals in Denmark, hence competition is weak and the prices for using the terminals are high. The solution is not clear, but a new, open terminal capacity would improve the situation and make rail transport more competitive.

5. **The railway Oslo-Gothenburg**. The railway between two of the largest Nordic regions has major flaws concerning line speed, steep gradients and length restrictions affecting cost efficiency very negatively.

6. The railway system in the Oslo region and the Alnabru terminal. The railway network in the Oslo region has severe capacity challenges because of large passenger flows as well as freight volumes. The Alnabru terminal is the largest in the Nordic countries. It has capacity constraints and must be further developed to promote a modal shift.

7. The Western Main Line in Sweden. It might be the most important railway in Sweden with large flows of both passengers and goods, but lack of capacity has deteriorated traffic quality, leading to disturbances and longer transport times.

8. The Southern Main Line in Sweden. This is also a competitor for the title most important Swedish railway. There is currently no decision to increase capacity to and from the Greater Copenhagen Area.

9. Train lengths in Sweden and Norway. Longer and heavier trains have a large potential of increasing railway competitiveness. Current restrictions in Norway and Sweden are obstructing that potential.

Category B

10. Hamburg - Lübeck - Puttgarden (Hinterlandanbindung FBQ). It is part of the state treaty between Germany and Denmark and must be ready when the FBFL opens, otherwise, it will be the most serious bottleneck in the STRING corridor.

11. Danish bottlenecks around Copenhagen. Existing bottlenecks around Copenhagen will be even more severe when the FBFL opens. There is a great need for track junctions separated in height in Ringsted and Ny Ellebjerg, and to ensure sufficient railway capacity at and to and from Copenhagen Airport station with new passing tracks and other measures. These projects are prioritised in the Danish Infrastructure plan (Transportministeriet 2021a). The double-track stretch from “Hvidovre fjern” to Høje Taastrup may be a future bottleneck.

12. Swedish bottlenecks around Malmö. There is a need to ensure capacity around Malmö and to and from the Öresund Fixed Link, not the least a grade-separated rail junction in Svågertorp and increased capacity of the marshalling yard in Malmö.

13. The West Coast Line around Gothenburg. South of Gothenburg, capacity constraints are obstructing the development of rail transport for passengers as well as freight.

14. ERTMS. The new European standard signalling system will, according to plans, have important benefits for freight transport. Though the time schedules are vague, the system will not be fully developed in the STRING countries until earliest the mid-2030s.

15. Strategic redundancy across the Öresund. There is an obvious risk that the railway ferries between Trelleborg and Rostock will cease to operate, due to low profitability. It would be troublesome to lose redundancy between Southern Sweden and Germany about at the same time as redundancy through Denmark is established.

Due to the long lead times for planning and construction all challenges in both categories must be addressed immediately.

Recommendations

The analysis in this report results in clear conclusions. The tunnel under the Fehmarn Belt makes valuable contributions to strengthening rail freight in the STRING corridor, but it is not enough to lead to a substantial modal shift. It therefore appears to be a necessary, but not sufficient, instrument for an enhanced role for rail freight in the corridor. None of the most positive scenarios in this report indicate that the EU's ambitious targets for shifting from road to rail will happen. A variety of complementary initiatives are needed to enable such a development and to fully utilize the FBFL. This report highlights the following measures and recommendations to strengthen rail freight in the STRING corridor:

- **Removing infrastructure bottlenecks is crucial for railway growth**. Capacity constraints have very negative consequences for all factors defining the competitiveness of transport modes.
- **Ensuring full train lengths and faster trains in the entire corridor and its connections will improve railway competitiveness**. It will increase rail freight transport capacity as well as enable more trains in the network.
- **The infrastructure standard in the TEN-T freight corridors is not sufficient, but rather represents a minimum standard**. The standard does not take into consideration capacity constraints hindering full utilization of the railway network, nor steep gradients (for example between Oslo and Gothenburg) and other bottlenecks.
- **There is a need for more terminals in Denmark**, or multiple operators within each hub/terminal, to ensure competition that contributes not only to railway cost efficiency, but also to increased reliability and capacity.
- **A level playing field between transport modes regarding fees and taxes is necessary**. This should ensure that all transport modes pay for their externalities.
- As road transport is expected to remain the dominant freight transport mode in the STRING corridor, any effort that minimizes greenhouse gas emissions from road vehicles would be just as important as paving the way for more rail freight. **Providing necessary infrastructure for zero or low-emission fuels is crucial in this respect.**
- **While railway transport has many advantages, sea transport could give significant contributions to the STRING corridor**, primarily for transport to and from the corridor. Railway bottlenecks could be partially relieved if cargo is transported by ship to a seaport closer to the origin or destination, before being transferred to rail transport (see for example Stelling et al 2019).

The German construction site on the island of Fehmarn (as of January 2023). At Puttgarden, works on the German portal and work harbour are ongoing. The construction of two of the three bridges required for the new alignment of B 207 (E47) and the railway line is being prepared. After the opening of the Fehmarnbelt tunnel, the Danish island of Lolland, which can be seen on the horizon, will be 10 minutes away by car and 7 minutes by train.
Source: Femern A/S

Table of contents

1. Introduction

This chapter presents the background and purpose of the study as well as the method. The chapter ends with an introduction to the project organization, reading instructions and a small glossary.

1.1 Background

The STRING transport corridor connects Hamburg and Oslo via Copenhagen, Malmö, and Gothenburg. The region is an essential part of the Scandinavian-Mediterranean transport freight corridor (Figure 5) with 14 million inhabitants and many leading industries and important transport nodes.

The STRING geography has massive economic activities, particularly concentrated in and around Hamburg, Lübeck, Copenhagen, Malmö, Helsingborg, Halmstad, Göteborg and Oslo

The STRING geography has massive economic activities, particularly concentrated in and around Hamburg, Lübeck, Copenhagen, Malmö, Helsingborg, Halmstad, Göteborg and Oslo. Such a concentration along a single corridor is potentially favourable for the demand of rail transport and could ensure large volumes and hence high efficiency, economically as well as environmentally. However, the market share for rail freight is currently low, and the efficiency and costs of the rail services not sufficiently competitive.

The tunnel under the Fehmarn Belt between Denmark and Germany is planned to open in 2029.[6] The fixed link is 18 km long and the world's longest immersed tunnel, connecting Rødbyhavn in Denmark with the island Fehmarn in Germany. It eliminates the need for a 160 km long detour through Denmark for freight trains. The tunnel will have two tracks for trains and four lanes for road traffic. The total budget is 55 billion DKK, including financial reserves. The tunnel will be refinanced by user payments.

The Fehmarn Belt Fixed Link (FBFL) will remove a bottleneck and reduce transport times, contributing to efficient logistics between Scandinavia and Continental Europe. This could be an opportunity to realize the potential for more rail transport.

However, it is crucial to ensure the railway's capacity to avoid a situation where passenger trains and freight trains compete for time slots on the tracks. Capacity constraints and bottlenecks could effectively limit the potential positive impacts of rail transport. It is also important to take complementary measures to increase the competitiveness of rail transport, for example by enabling higher degree of competition between service providers and allowing longer and faster trains.

[6] For more information on the fixed link and the construction works, visit www.femern.com

Figure 5. The Fehmarn Belt Fixed Link is part of the EU TEN-T network and the ScandMed-corridor. Map: European Commission. Source: Femern A/S

1.2 Purpose

The purpose of this study is hence threefold:

- To describe possible future rail freight volumes across the FBFL in 2030, 2035 and 2040.
- To identify infrastructure problems and other obstacles or barriers that must be solved to fully utilize the FBFL and increase railway competitiveness.
- To propose solutions on how to overcome the challenges identified in step 2, thereby closing the gap between forecasts and EU targets.

Focus of the study is rail freight transport, reflecting the political ambition to transfer cargo from road to rail as well as the challenges for achieving this. Still, road transport is discussed extensively and scenarios for future road freight volumes are also included.

1.3 Method

Many transport forecasts use advanced statistical or econometric models. Though these models have advantages, they may also be perceived as “black boxes” where it may be difficult to understand what happens between input and results. Hence, their transparency and usefulness as discussion material may be limited.

In this study, a different approach is chosen, partly due to budget and time constraints of the project, but also with the ambition to be highly transparent, allowing the reader to follow the analysis and judge whether they agree with the conclusions or not.

Central to the study is a combination of quantitative data with qualitative assessments. The project team has consisted of four professors within freight transportation, logistics and supply chain management from Norway, Sweden, Denmark, and Germany together with two senior consultants from Sweco. Experts from Sweco have participated to shed light on specific aspects.

To answer the three questions forming the purpose of this study, rail transport in the STRING corridor have been studied from different perspectives (Figure 6).

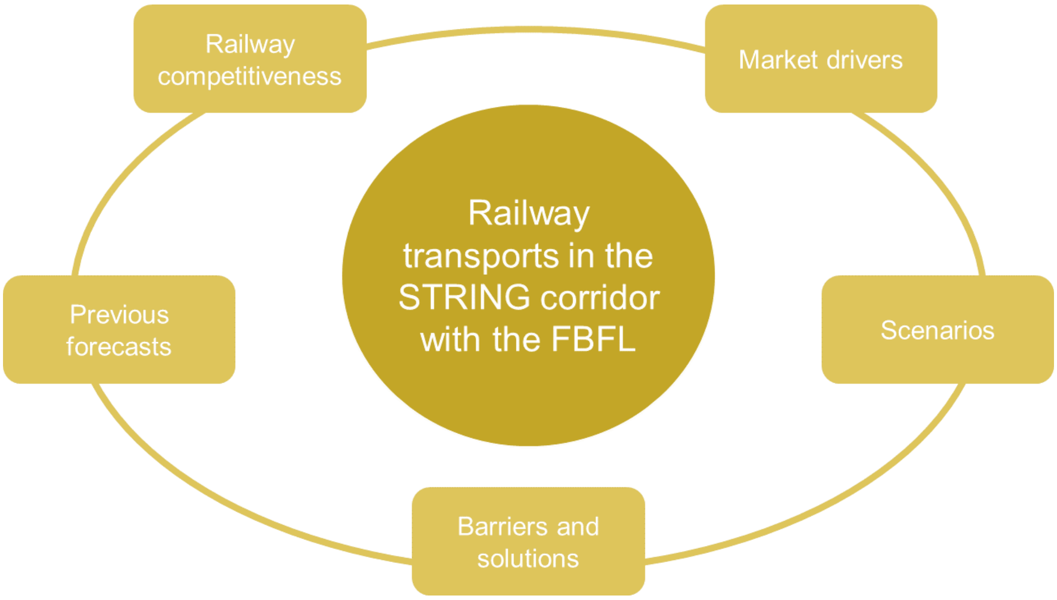


Figure 6. Analysing the issue from different perspectives.

The first step has been an explorative literature study on railway competitiveness, identifying the strengths and weaknesses of this transport mode in the light of logistics trends and market drivers. This establishes a background for studying the effects of the FBFL.

The results from the latest, model-based transport forecast from 2014 by Intraplan and BVU are compared with the actual development of freight volumes up until today. Plausible explanations of the gap between the forecast and the factual numbers are discussed. The forecast from 2014 was reviewed by Cowi (2015), concluding that the forecast was of high quality. The forecast is used as a starting point for this study.

To deal with the uncertainties associated with the forecasts four scenarios are formed. The basis for the scenarios has been railway freight volumes through, to and from Denmark together with volumes on the ferries between Southern Sweden and Germany. This is further discussed in Appendix 1. The uncertainties are highlighted to give the reader an understanding of the complexity involved.

Barriers to railway development in the STRING corridor have been identified as well as possible suggestions for dealing with them, hence increasing railway attractiveness.

The study has had a focus on the most important aspects to avoid getting too much into details. Freight transports between Norway/Sweden/Denmark and Germany/Belgium/Netherlands/France/Austria/Italy/Poland have been studied, since these are the relations that seem to be the most important ones for the future fixed link.

In general, the ambition has been to use long-time perspectives when analysing trends. That has not always been possible because of a lack of data. There have been no specific adjustments for the years of the Covid-19 pandemic.

1.4 Organization

Rebecca Rosenquist Elliott, Deputy Director of the STRING Network, and **Anna Engblom**, Senior Advisor at the Greater Copenhagen Committee, have been the clients' project managers.

The project team consisted of experts and consultants from Sweco. The experts are all professors in logistics at leading universities in Germany, Denmark, Sweden, and Norway. The professors have participated as individual experts and do not represent their universities in the study.

Otto Anker Nielsen is professor of Transport Modelling at DTU, University of Technology in Denmark.

Ralf Elbert is professor of Management and Logistics at Technical University of Darmstadt in Germany.

Harald M. Hjelle is professor of Transport economics at Molde University College, Specialised University in Logistics, in Norway.

Johan Woxenius is professor of Maritime Transport Management and Logistics at the University of Gothenburg in Sweden.

The Sweco project team has consisted of senior consultants **Henrik Andersson**, specialized in strategy development and **Johan Johansson**, specialized in transport infrastructure.

The entire project team is responsible for the analysis, conclusions, and recommendations, while Sweco alone is responsible for numbers and data presented in the report.

Infrastructure strategists from the STRING Network and members of the Greater Copenhagen Committee have functioned as a reference group during the process. The project team is very grateful for their valuable input to the analysis.

1.5 Reading guide and glossary

Chapter 2 introduces the railway market and discusses trends and market drivers.

In **chapter 3**. the previous forecasts for the FBFL are compared to actual traffic development.

This is followed by the development of four scenarios for railway freight volumes on the FBFL in **chapter 4**.

Chapter 5 analyses how railway competitiveness can be improved and the relative contribution from the FBFL.

In **chapter 6** capacity constraints and their urgency are discussed.

The report ends with recommendations in **chapter 7**.

In the report, several terms and abbreviations are used. Most are explained where they appear, but the following brief glossary cover terms used more frequently.

- *Compounded Annual Growth Rate (CAGR)*: The annual, average growth rate over a period.
- *Feeder transport:* A smaller transport, transferring cargo to a larger transport.
- *Intermodal transport:* Referring to a transport using at least two different transport modes, for example road and rail.
- *Passing loop or tracks:* Parallel railway track/tracks to enable trains to meet or pass each other.
- *Pre-/ post-/ or end-haulage*: The transport between the origin and a terminal, or from the terminal to the destination.
- *Railway ferries:* Ferries with specific railway tracks, allowing for wagons to be rolled on board.
- *RoRo:* Ships allowing trucks to roll directly on board (and off).
- *RoPax:* Ships allowing trucks to roll directly on board (and off), but also carry passengers.
- *Semi-trailer:* A trailer with no front axle. A semi-trailer Is pulled by a tractor unit.
- *Shipper:* The company ordering the transport from one place to another. It is often the owner of the cargo.
- *Transport work*: moving cargo in tonnes a distance in kilometres, hence the unit *tonne-km (tkm)*. 1 tkm equals 1 tonne of cargo being transported 1 kilometre.

2. Railway competitiveness

This chapter discusses railway competitiveness as a background for analysing the previous forecast for the FBFL as well as actual rail freight development and the scenarios for freight volumes on the FBFL presented in chapter 3.

2.1 Railway market share and market trends

Rail freight operations include three main products: trainload, single wagon load and intermodal (Islam et al 2016 p.4).

- Trainload means full trains operating for a single company, often from origin to destination in a shuttle. They are also referred to as system trains.
- Wagonload means traditional single wagon loads, transported by a rail freight operator to a marshalling yard or terminal. Here the train is consolidated and hauled to the destination terminal or marshalling yard, where the train is divided, and the wagons transported to the customers' side-tracks.
- Intermodal traffic refers to cargo in containers, swap-bodies, and semi-trailers, that are loaded on and off trains at terminals.[7] Intermodal transport utilizes the advantages of road and rail freight transport by combining the flexibility of road for the pre- and on-carriage with the mass carrying capacity of rail in the main run.

European rail freight transport has in general had difficulties in maintaining its market share. In the 1950s, the rail freight market share was around 60 % (McKinsey & Co 2022 p.2). Today, it is below 12 % (Table 4).

European rail freight transport has in general had difficulties in maintaining its market share. In the 1950s, the rail freight market share was around 60 %. Today, it is below 12 %.

Table 4. Modal split in EU-27, based on tonne-kilometres. Source: European Commission 2022 p.36.

	Road	Rail	Inland waterways	Pipelines	Sea	Air
1995	46.9 %	15.6 %	5.1 %	4.3 %	28.1 %	0.1 %
2020	53.3 %	11.5 %	5.0 %	2.8 %	28.2 %	0.1 %

Table 4 shows how large-scale transport modes like rail, inland waterway and pipeline have gradually lost market share. Sea is also large-scale, but globalization has increased the demand for longer transport in relations where ships are the only

[7] The description of the products is to a high extent based on Islam et al (2016 p.4).

alternative and feeder shipping helps explain that the sea has kept its market share in the EU-27.

In the countries in the STRING corridor, the pattern is slightly more positive during the period 2005-2020, see Figure 7. As transport volumes have increased during the period, rail has been able to keep its market share in Germany, Denmark, and Norway. In Sweden, rail has lost market shares during that period.

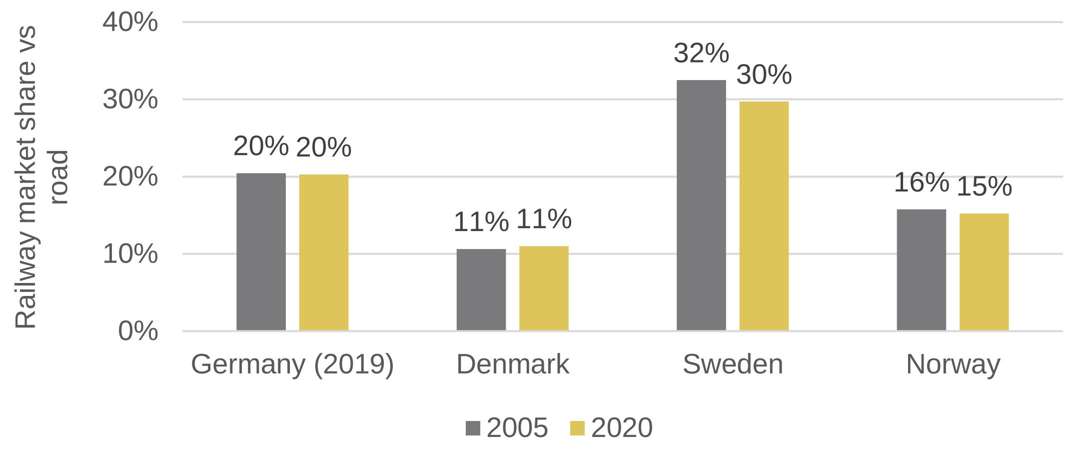


Figure 7. Modal split railway versus road, based on tonne-kilometres. The numbers only compare rail with road but includes all transports performed by these modes. For Norway and Sweden, ore is included. Source: European Commission 2022 pp.41-42; Sweco.

Figure 8 shows rail volumes from 2011 in the four countries included in the STRING corridor. As iron ore is very dominant for Swedish and Norwegian rail transport, they have been excluded. Since 2011, Norway and Sweden have experienced a rising demand for rail transport. In Germany, there has been a small decline, while rail volumes in Denmark have fallen during recent years.

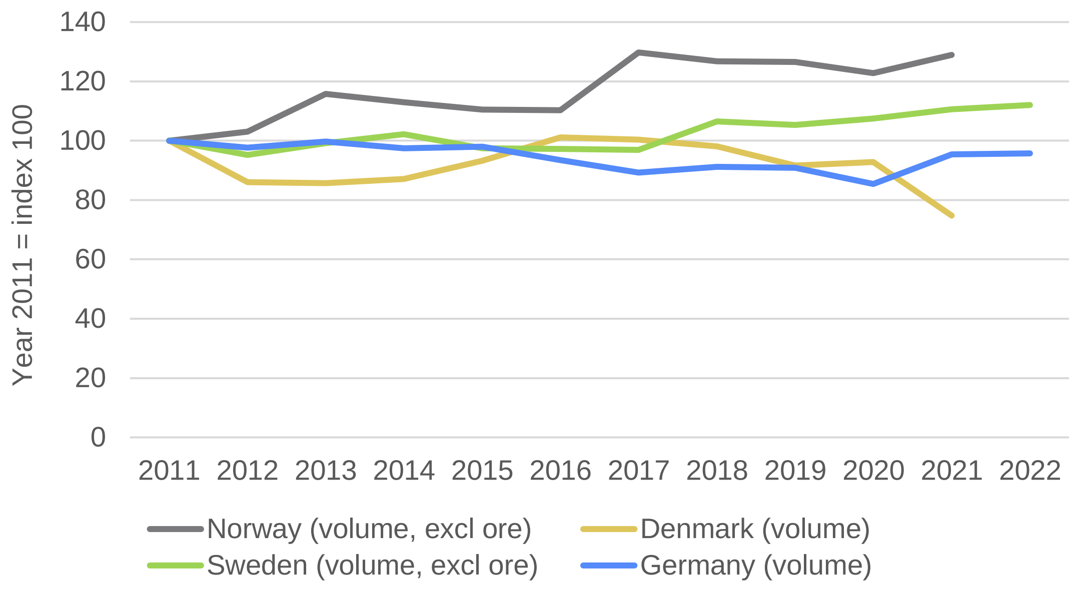


Figure 8. Rail volumes from 2011 (index 100). Both international, domestic and transit transport are included. Sources: Statistisk sentralbyrå Table 10511; Danmarks statistik Table BANE1; Trafikanalys Railway transport 2022 Quarter 4 Table 3; Statistisches Bundesamt Table 46131-0001.

The same pattern is apparent when it comes to railway transport work in tonne-kilometres (tkm), see Figure 9. The exception is Germany, where the length of transport seems to have increased during the last years, resulting in more transport work despite slightly smaller volumes. The positive development in intermodal transport is also decisive for this. Intermodal transport will likely continue to be the transport segment with the highest growth in volume in Germany (Intraplan and TTS Trimode 2023).

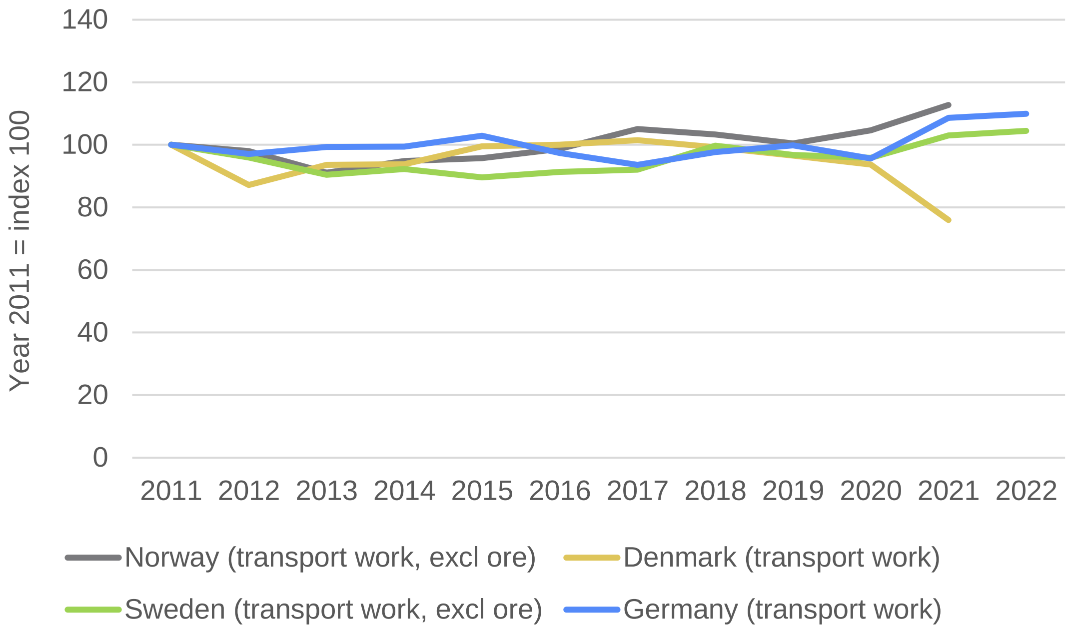


Figure 9. Rail transport work from 2011 (index 100). Both international, domestic and transit transport are included. Sources: Statistisk sentralbyrå Table 10511; Danmarks statistik Table Bane1; Trafikanalys Railway transport 20220 Quarter 4 Table 3; Statisches Bundesamt Table 46131-0001.

During the periods shown in Figure 8 and Figure 9, various developments have favoured or disfavoured the different transport modes. The railways' loss of competitiveness against lorries over the past two decades has partly been due to falling road transport prices. One reason is improved infrastructure with higher speeds and capacity (for instance motorway all the way from Oslo to the Norwegian/Swedish border), increased permitted weight and length of the vehicles and access to low-cost drivers. In Germany, road tolls were temporarily reduced in the mid-2010s, immediately affecting the modal split. In recent years, the railway has to some extent made up for the losses, mostly because the prices of road transport have increased significantly through fuel prices and shortage of drivers. However, one essential reason for road freight transport gaining market share during the last decades is that they have been able to meet a demand for high reliability, flexibility, and speed compared to more rigid, fixed, and slower rail freight services experiencing punctuality problems. This is a central aspect when studying future transport patterns.

One essential reason for road freight transport gaining market share during the last decades is that they have been able to meet a demand for high reliability, flexibility, and speed.

There are more underlying trends that have favoured road and/or disfavoured rail (developed from Tavasszy and van Meijeren 2011 p.5; McKinsey & Co 2022 p.3; Rail Freight Forward Coalition 2018 p.8):

- Increased value density of goods and the associated demand for new/improved services, such as faster and more flexible and reliable transport to enable just-in-time production and reduce capital costs, smaller lot sizes, and decentralized flows.
- Privatization of transport markets in Central and Eastern Europe has typically favoured road. The expansion of the European Union has increased the supply of low-cost road transport.
- Modest growth in domestic transport flows, where railway transport is not hindered by barriers.
- Many traditional customer industries for freight rail have been declining, both in relative and absolute terms. For example, in Germany, the transported volume of coal, iron and metal was reduced by 85 million tonnes between 1970 and 2017 (McKinsey & Co 2022 p.3).

The slower growth of market segments where railway competitiveness has traditionally been strong, is expected to continue. McKinsey & Company (2022 p.3) states that traditional railway segments are expected to decrease by 1 % a year until 2030. This is also shown in Table 5. Of the total transport market in 2025, more than 46 % of the transport work is expected to be types of goods with low rail affinity.

Table 5. Transport market structure in EU-27 by categories of goods 2014-2025. Source: Rail Freight Forward Coalition 2018 p.9.

Segment	Transport demand	Example of goods	Share of total transport performance in tkm		
			2014	2025	Change 2014-2025 (units)
Low rail affinity	Short transport times High reliability Small lots Need for last mile track access	Food, machinery, grouped goods	39.2 %	46.3 %	+ 7.1 %
High rail affinity	Large volumes Heavy/dangerous goods Stockpiling	Coal, ore	21.0 %	17.2 %	- 3.8 %
Some rail affinity	Heavy/dangerous goods Flexibility in transport time Oversized	Wood, chemicals	39.8 %	36.2 %	- 3.6 %

Decreasing rail volumes lead to a vicious circle of an increasing share of fixed costs, hence loss of competitiveness. Therefore, volumes are further reduced, and the share of fixed costs increases even more (McKinsey & Co 2022 p.2). Larger and heavier trucks as well as rail capacity constraints further deteriorate rail competitiveness.

Nevertheless, there are also trends and developments that should basically favour rail:

- Climate change, where railway outperforms road transport, especially in countries with fossil-free energy production. Climate change should increase rail competitiveness relative road and often also versus sea, either directly (through demand from customers) or indirectly (through higher taxes on carbon dioxide).

Climate change should increase rail competitiveness relative road and often also versus sea.

- Rising energy prices, benefitting the superior energy efficiency of the railway. Although the performance of electrified, heavy road traffic may increase rapidly, rail traffic has significantly superior energy efficiency compared to both trucks and shipping (IVL and Chalmers 2019).
- Recent events such as the pandemic, Russia's invasion of Ukraine and increased trade barriers have illuminated vulnerability in geographically long-range supply chains. The International Union of Railways and the European Rail Freight Association (2020 p.2) argues that railway transport proved to be very resilient during the pandemic, with rail freight being the only mode of transport not significantly affected by the lockdowns. The turbulence in the world could lead to increased safety stocks in industries (just-in-case instead of just-in-time), reducing the need for speed. It could also lead to reshoring of industry production, increasing demand for freight transport within Europe. Business Sweden (2022) highlights a) that Swedish industry has most of its suppliers in Europe, equally divided between Western and Eastern/Central Europe, and b) that many companies are shifting from Chinese suppliers to European. Their first choice is Eastern Europe, and second is Western Europe. It should be noted, however, that this development might also lead to higher costs for wages and hence lower competitiveness on the world market. Northern Sweden and parts of Norway are experiencing a new wave of demand for industrial production, driven mainly by a favourable access to green energy and raw materials.

Looking close to 20 years into the future, the uncertainties are obviously substantial. Still, Table 6 comments market drivers influencing the modal split.

Although rail has struggled for many years because of developments that favour road, some market trends together create a window of opportunity for rail growth. This is enhanced by the FBFL, although that project alone is not sufficient to change modal shares by much.

This chapter has so far focused on competition between road and rail. Although the actual competitive surface between road and rail is small[8], for long-distance transport, rail has a clear potential to be competitive. This will benefit the environment and is expressed in political ambitions. It is worth noting that there is a large existing market of road transport in the STRING corridor. This means that future growth is of less concern. The primary challenge is to increase rail competitiveness to win market shares of existing transport volumes.

Illustration of tunnel portal in Denmark. Source: Femern A/S

[8] Tavasszy and van Meijeren (2011 p.7) estimate that 11 % of road transports in the EU-27 are longer than 300 km.

Table 6. Market drivers influencing modal choice.

Development	Modal choice	Logic and brief comment including examples of activities
Demand for transport	Rail: + Road: ++	The total market is expected to grow, but higher value and specialization lead to more fragmented transport and need for speed gives a natural advantage for road freight. Reshoring might strengthen traditional railway segments.
Energy prices	Rail: + (< 2030) + (< 2040) Road: -- (< 2030) - (< 2040)	Increasing energy prices will affect all transport. Railway should benefit from superior energy efficiency, but the net effect on modal shift is uncertain, especially in the longer term. Norway estimates that battery/electric trucks will be cheaper than diesel trucks by 2030 (Transportetatene 2023b p.4). Green Cargo says that energy costs in Norway increased from 4 % to 20 % of total rail operating costs 2020 and 2022 (Järnvägar.nu 2022).
Climate and environmental consideration	Rail: ++ <2030 + < 2040 Road: -- < 2030 -/0 < 2040	Will affect demand directly or indirectly. Railway should benefit from superior energy efficiency, but the net effect on modal shift is uncertain, especially in the longer term. Sea transport will be included in European Emission Trading System for climate gases, increasing costs. Also, the new IMO CII regime will lead to increased costs or slower shipping services – especially for RoRo services. Road pricing is expected in 2025 in Denmark, but primarily for covering maintenance costs rather than reducing climate emissions. Emissions of particulate matter from trucks cause severe health problems. Noise is a challenge for road and rail alike.
Capacity constraints and congestion	Rail: - < 2030 -- < 2040 Road: + < 2030 0/- < 2040	Railway capacity constraints are much more serious for longer transport, albeit road congestion is severe around the larger cities. In a business-as-usual scenario, the situation will worsen. Railway capacity is deemed critical for developments in the STRING-corridor, which will be further discussed in chapter 6.
More focus on sustainability by politicians and authorities, investors, and other stakeholders	Rail: + Road: -	EU's mobility package aims at ensuring fair competition, improved working conditions and illegal sabotage. It is practically aimed at road transport and will affect competitiveness negatively in the short term. ESG (Environment, Social, Governance) and other sustainability reporting practices/requirements might be a future driver for rail, at least until road catches up.
Access to drivers	Rail: - Road: --	Although the challenge might be larger for road, it is also problematic for rail. The lack of truck drivers increases costs but also reduces capacity. It might also affect first and last mile transport for intermodal transport, as well. Day jobs driving around intermodal terminals are likely to be more attractive than driving long distances over-night or for several days.
Shortage of rolling stock	Rail: - Road: 0	While road transport has grown steadily over decades, can the railway industry adapt to sudden, fast growth?

2.2 When is rail freight transport competitive?

What are the necessary conditions for railway transport? When and where is rail "naturally competitive"? This is commented below, based on Tavasszy and van Meijeren (2011 p.10):

- **Accessibility of transport modes**. All regions are accessible by road, but other transport modes are dependent on closeness to a port, airport, rail, or intermodal terminal and a pre- or on haulage. An essential proportion of rail freight transport is accounted for the intermodal road/rail freight transports, utilizing both road and rail. In the STRING corridor in general, geographic access to terminals and important nodes is comparatively favourable. However, there are challenges such as capacity constraints, monopoly-like situations, and high prices in terminals, which will be further discussed in chapters 5 and 6.

- **Shipment size**. The larger the size of the shipment in tonnes, the higher the chance of using rail or sea. Rail is typically competitive for shipments equalling the capacity of a rail wagon, i.e., 20 tons or more. This partially explains why container transport is a significant market segment for rail. In the STRING corridor, with a large population and many relatively large regions, consumer goods make up an important part of freight volumes. For rail to be competitive in these segments, it is often necessary to stuff in containers. For wagonload to be an alternative, the transport quality in times of reliability and time must be improved.

The larger the size of the shipment in tonnes, the higher the chance of using rail or sea.

- **Transport time**. When there is a need to deliver in a very short time, road freight is often faster. As a rule of thumb, for rail to be a viable option, shipments should be delivered in more than one day. Jernbanedirektoratet (2019a p.41) shows that for longer, domestic Norwegian relations, transport time via rail is very often just as fast as for road. Hence, the railway market share is for instance 53 % between Oslo and Trondheim and 55 % Oslo-Bergen (Jernbanedirektoratet 2019b).[9] In the STRING corridor in general, road transport is typically faster than rail from door-to-door.

- **Transport distance**. To cover the costs associated with the extra handling at terminals, the rail transport distance, for which freight trains have a cost advantage over the road, must be sufficiently long. There are examples of short distances, for instance shuttles connecting ports to their hinterlands[10], but the general picture is that railway needs 300 km and preferably longer. There is also a stepwise increase in competitiveness for longer distances than a truck driver can cover in one shift, roughly 600 kms.

[9] The comparison does not include sea transport, which is very small.

[10] The shuttle train between the Port of Gothenburg and the terminal in Falköping is ~130 km, for instance.

- **Product characteristics**. One way to describe what type of goods is preferable for rail is to look at the factors value density (Euro per m3) and package density (number of packages per m3). When these are low, interest costs and handling costs are less important, and rail's potential cost advantage becomes more significant when choosing transport mode. The underlying trend is that value density and package density is increasing, hence resulting in weaker growth for products with rail affinity. Still, in the STRING corridor, there are large road transport flows (see chapter 5.2) that could possibly be transferred to train if rail improves performance regarding reliability, frequency, and costs.

The last two aspects are demonstrated in Figure 10, showing the modal split for transport longer than 300 km for various types of goods.

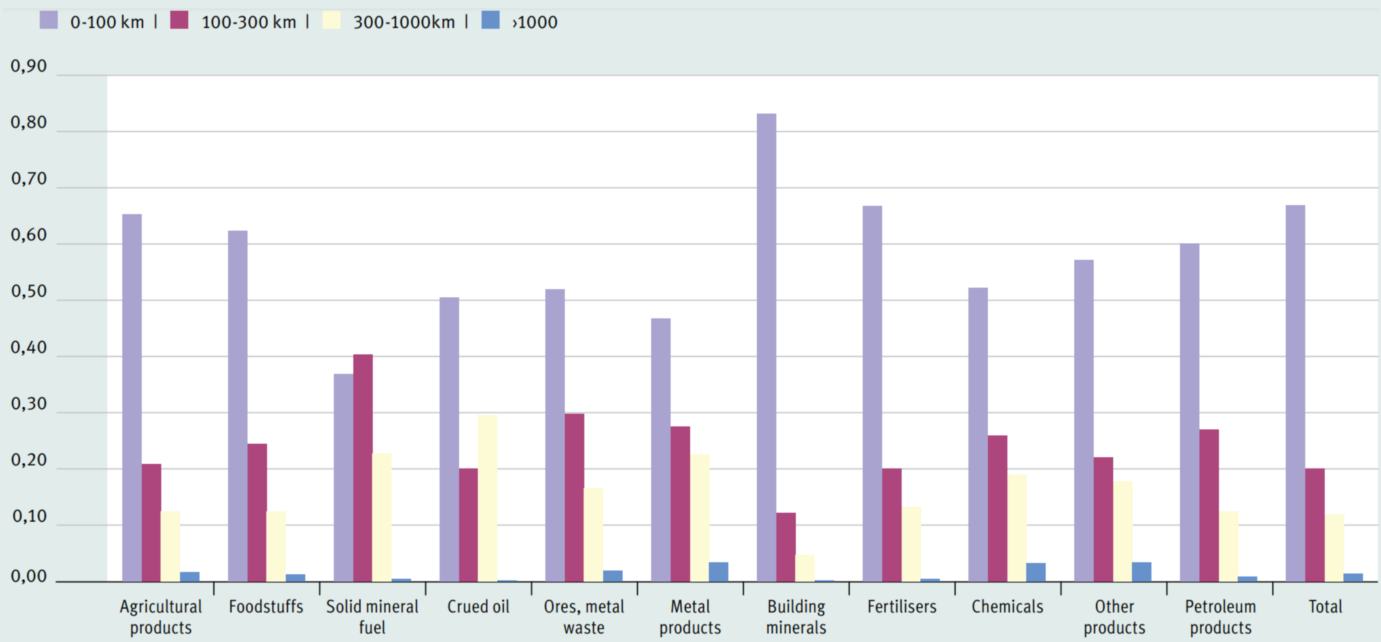


Figure 10. Modal split in the EU27 for transport longer than 300 km. Source: Tavasszy and van Meijeren 2011 p.6 with data from Eurostat.

Intraplan and BVU (2014 p.31) presented figures on the transported volumes between Scandinavia and the European Continent, and rail market share versus road (Figure 11).

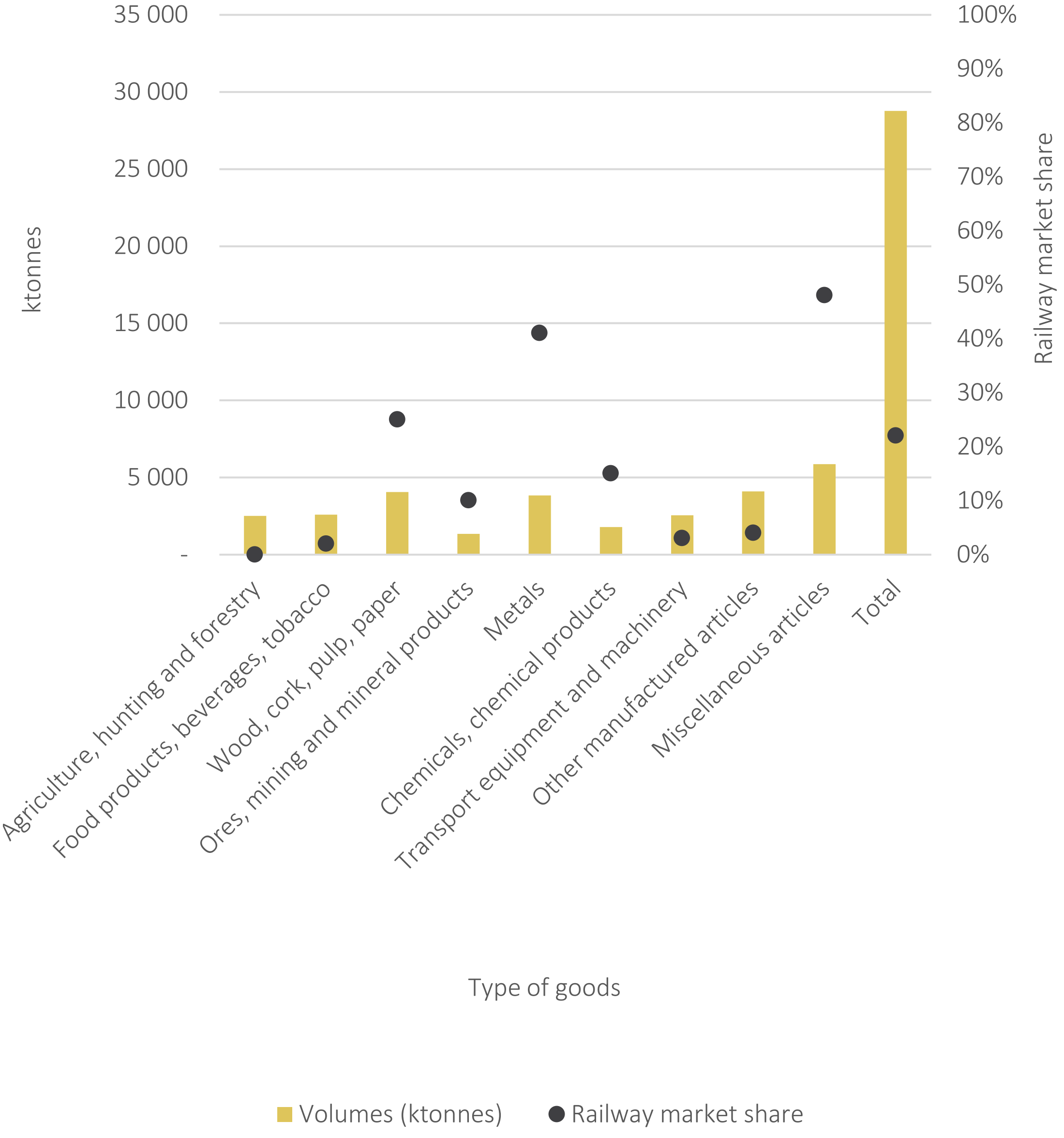


Figure 11. Transported volumes between Scandinavia and Continental Europe and rail market share versus road in 2011. Source: Intraplan and BVU 2014 p.31.

2.3 Conclusions – Railway competitiveness

In recent decades, rail has lost market share to the road, which has generally responded better to the demand for reliable and flexible logistics with short transport times. The railway is a large-scale system that requires large volumes of goods to achieve cost-effectiveness. It is difficult to draw unambiguous conclusions from different market drivers, but some tendencies together create an opportunity for rail freight to develop positively in the coming years. This applies, for example, to rising energy and fuel prices and a strong and growing focus on climate considerations, the environment and sustainability in general. However, a potential growth in volumes accentuates the limitations represented a rail network with serious and increasing capacity constraints. Many of these bottlenecks are already slowing rail freight growth and also take a long time to remedy through increased capacity.

From the perspective of the shipper[11], the buyer of the transport service and usually the owners of the goods: efficient logistics often combine different transport modes for various parts of the supply chain. Competition between the transport modes is favourable, resulting in improvements in time, cost, and quality.

From the perspective of society, competition between transport modes is often beneficial as well, adding to increased productivity. However, this competition must take into consideration the so-called externalities, how transport affect third parties.

From the perspective of society, competition between transport modes is often beneficial as well, adding to increased productivity. However, this competition must take into consideration the so-called externalities, how transport affect third parties. Typical negative externalities related to freight transport are emissions of climate gases, noise, congestion, wear and tear on infrastructure and accidents.[12] The European Commission (2019 p.158) states that the average external costs for rail transport are 1.3 €-cent per tkm. For road freight transport they are 4.2 €-cent per tkm, more than three times higher. Marginal taxes and fees on transport should reflect the marginal externalities. Trafikanalys (2022b pp.5-6) shows that in Sweden, heavy lorries with trailers running on diesel have a non-internalized cost of 0.15 SEK per tonne km. The same goes for sea transport, although it differs depending on the type of ship. A freight train has a non-internalized cost of 0.03 SEK per tonne km. This means that road and sea pay less for their marginal externalities than rail in absolute costs. Sweden is likely representative for countries within and adjacent to the STRING corridor. Although the balancing is sometimes problematic, taxes and fees should cover the external costs of each individual mode of transport. If there is no alternative to road transport, it is better to support those industries in other ways (if that is deemed desirable for society), while keeping the incentives to reduce negative external effects.

[11] The company ordering the transport from one place to another.

[12] There are positive externalities as well. One example is employment.

Although there is a political ambition to promote sea transport as well as rail transport, they are sometimes competing. In the STRING corridor, the foremost function of sea is however transport to/from the geography, though sea freight might also be able to compete in specific relations along the corridor. A specific possibility is feeder ships from smaller ports in the corridor to the large gateway ports within or close to the corridor, notably the Port of Hamburg. Sea transport is facing some serious challenges and might lag behind both rail and road in the shift towards zero/low emission technologies. The costs for transforming ships' engines and switching to alternative fuels are high and the longevity of the vessels means that the average fleet performance is shifted slowly. This could mean that electrified road transport and rail will be preferable to sea transport in an intermediate perspective, approximately from the mid-2030s. Sea transport being included in the European Emission Trading System will lead to a significant cost increase, likely resulting in a modal shift away from RoRo/RoPax shipping (Hansson et al 2022 p.5). Also, the IMO regime related to the Carbon Intensity Indicator (CII), which is recently implemented, could mean that sea feeder transport or coastal shipping become less competitive versus other modes.

There is a general picture that lorry producers are more innovative than the rail equipment industry. One important reason is that there are more truck manufacturers, hence more competition that favours innovation. Innovations also spread faster through the shorter life span of a lorry compared to railway equipment and ships. Hence, rail freight operators expect road transport innovation to "reduce the price of road transport tremendously" through technologies and concepts such as high-capacity trucks (longer, heavier trucks), platooning (connecting lorries and trailers into "road trains"), autonomous driving and electrification (Road Freight Forward 2018 p.8). The effect of longer trucks is illustrative. The modular system allowing combinations based on semi-trailers and swap bodies, reaching 25.25 m vehicle length (see Figure 12), has proved to be successful on the fixed link across the Öresund.

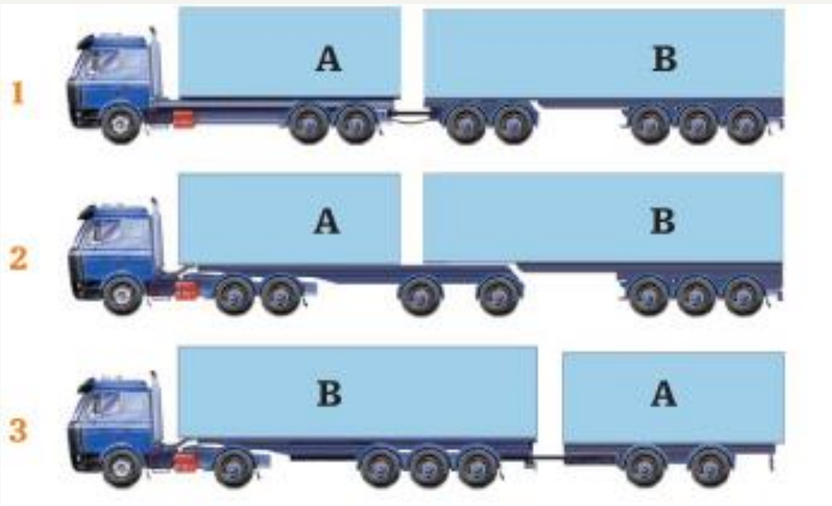


Figure 12. Combinations utilising the modular system of 25.25 m. Source: Transportstyrelsen 2023.

Introduced in 2008, the number of trucks were 20 900 in 2015 and 33 300 in 2019, equalling an annual growth rate of more than 12 %. The market share increased from 4.7 % to 6.5 % (Ramboll and Moe Tetraplan 2020 p.20). It should be noted that the modular system legislation stipulates unit loads and thus opens for intermodal competition compared to road freight using rigid trucks and trailers.

Regarding heavier trucks, the Swedish Transport Administration modelled the effects of allowing 74 tonnes trucks on all roads open for heavy traffic. This reduced expected railway growth until 2040 from 1.6 % per year to only 0.6 % (Trafikverket 2020 p.44).

There is a perception that rail is primarily suitable for heavy and relatively low-value goods. Norwegian experiences suggest that this may be challenged, with Cargo Net transporting salmon to Continental Europe by rail. DHL (2022) markets shipping parcels by train, Real Rail transports flowers, fruits, and vegetables from Southern to Northern Sweden and Scandfibre Logistics stuffs northbound trains to Sweden with food and consumer products from Italy and other countries. Crucial to enabling these transports is the reliability of rail services. Other product groups deemed to have the potential for transfer are, for example, forest products, some building materials, chemical products, machinery, and transport equipment (VTI 2021).

3. Previous forecasts and actual development

This chapter starts with a brief description of the fixed link under the Fehmarn Belt, summarizes previous forecasts and compares the latest forecast from 2014 with the actual development. The chapter ends with conclusions and a short discussion.

3.1 The direct effect of the fixed link

For transports between Scandinavia and Continental Europe, including global ports such as Hamburg and Rotterdam, the fixed link will lead to a reduction of transport distance, time, and associated costs. Freight trains will benefit relatively more than lorries, as the former today use the detour via Western Denmark, a single-track section in southern Jutland and sections with insufficient capacity at west-Funen. Some direct effects from the fixed link for transport are shown in Table 7.

Table 7. The direct effect of the fixed link on rail and road transport.

	Freight trains	Trucks
Transport distance	Reduced 160 km	Increases with ~20 km instead of ferry transport
Transport time	Reduced approximately 2.5 hours	Reduced approximately 60 min[13]
Transport cost[14]	Reduced operating and capital costs	Reduced operating costs are partially offset by driving in the tunnel.
Reliability	Adds strategic redundancy through Denmark with potentially more connections and departures, increasing resiliency.	Reduces dependency of ferries.

The effects of the FBFL are further analysed and discussed in chapter 5. The European Commission (2020b p.7) describes how the fixed link will benefit society:

[13] On average 15 minutes waiting time/check-in, 45 minutes transport with ferry and 15 minutes of embarkation minus driving time for a lorry (Intraplan and BVU 2014 p.18).

[14] The cost for passing the tunnel is a quite complex matter, as it concerns regulations on state aid as well as conditions for the financial contribution from the EU. It is assumed that the total railway fee for trains going from/to Hamburg via the Fehmarn Belt Fixed Link should equal the total railway fee for trains going via the Great Belt Fixed Link. See for example the European Commission 2020b p. 34.

> *"The Fehmarn Belt Fixed Link project will lead to a number of other positive impacts in terms of environmental impact, employment, regional development, improvement of trading conditions and a general strengthening of the transport sector. In combination with the Øresund Fixed Link between Denmark and Sweden, which has been in operation since July 2000, the Fehmarn Belt Fixed Link project will thus bring about a considerable improvement on one of the most important land-based transport corridors connecting Scandinavia with Central Europe."*

3.2 Previous forecasts

During the 2000s, there have been three more official forecasts for the fixed link across the Fehmarn Belt. The first is from 2002 and was updated in 2012 using projections based on recent traffic statistics. A new prognosis was published in 2014 (Intraplan and BVU 2014).

Intraplan and BVU (2014) assumed that the FBFL should have opened in 2022, resulting in shifts of routes as well as transport modes. The shifts are comparatively small, which is shown in the small step breaking the curves around the year 2022 in figure 13. Railway volumes were projected to increase to between 9.4 million tons and 11.8 million tons by the year 2047 in two different scenarios ("cases A and B"). From the base year 2011 to 2047, the increase was projected to be between 109 % and 167 % including the effect of the FBFL (Figure 13).

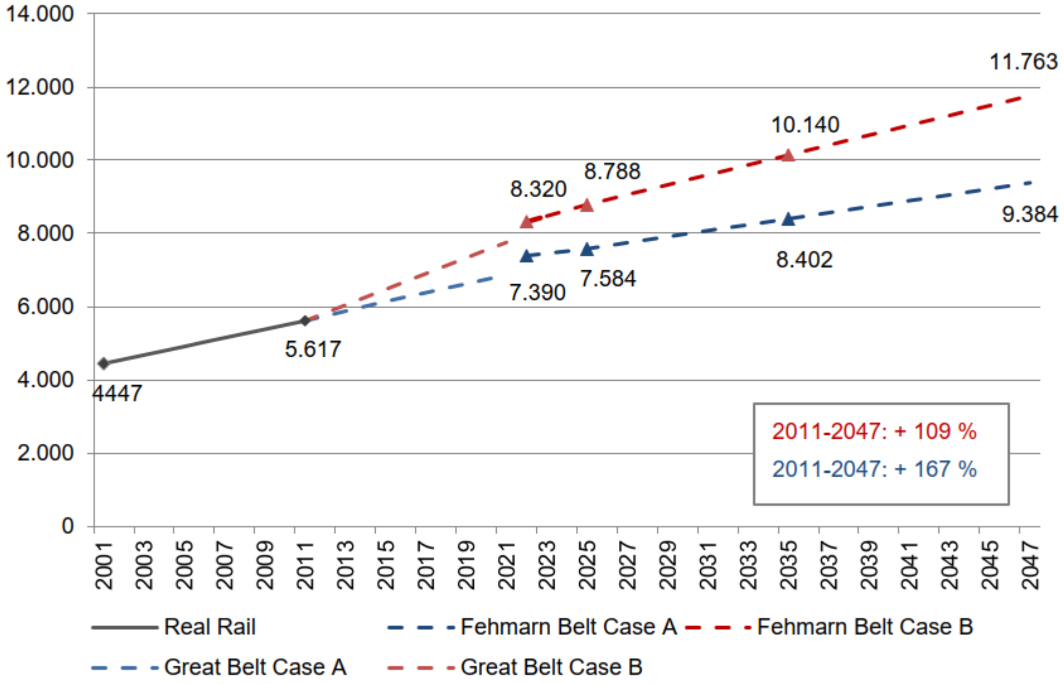


Figure 13. Forecast of rail freight volumes in 1 000 tons per year. Source: Intraplan & BVU 2014 p.193.

Case B is presented as the main scenario and case A is a sensitivity scenario. Case B used assumptions regarding population growth, economic forecasts, and development of infrastructure from the Danish Ministry of Transport, Ministry of Finance and OECD, while case A used the same assumptions as the German national transport plan.

Intraplan and BVU (2014 p.194) compare the results from the three, major prognoses conducted up until then, see Table 8.

Table 8. The prognosis from 2014 is significantly lower than the previous ones for the year 2025. Source: Intraplan and BVU 2014 p.167.

Freight traffic	**2025 results**				
Year of the study	Study from 2002		2012 (extrapolation of study from 2002)	Forecast from 2014	
Volume (1000 t/year)	Low	High		Case A	Case B
Road	8 700	10 700	-	6 600	6 870
Rail	10 500	12 700	11 500	7 600	8 800

The difference between case B and the forecast from 2002 in total land transport volumes is large, close to 7.8 million tonnes. The primary explanation is the 2008 financial crisis but also a weaker development of rail transport than expected (Intraplan and BVU 2014 p.97). For rail transport, the difference is ~3.9 million tonnes.

In the updated forecast from 2012, railway volumes are somewhere in between the scenarios from the prognosis from 2002 with 11.5 million tonnes. Hence, the main scenario from the 2014 forecast is 2.7 million tonnes lower than the 2012 prognosis.

In 2035, the forecast is 10.1 million tonnes (Figure 13). Based on an average load of 580 tons and 255 days of operation per year, 10.1 million tonnes equal 74 trains per day (Intraplan and BVU 2014 p.168). With current weights per freight train in Denmark, 10.1 million tonnes equal about 55 trains per day.[15]

The Danish authority Trafik- och Byggestyrelsen (2016) analyses the number of trains per day, resulting in a maximum number of 78 freight trains per day on the FBFL. They also estimate that 17 trains will traffic the current railway between Jutland and Germany. Hence, 82 % of railway freight is either transit through Denmark or international traffic to/from Eastern Denmark, while 18 % is international traffic to/from Western Denmark.

Intraplan and BVU (2014) present where the railway volumes come from when the fixed link opens. A major part is from existing rail transport through and to/from

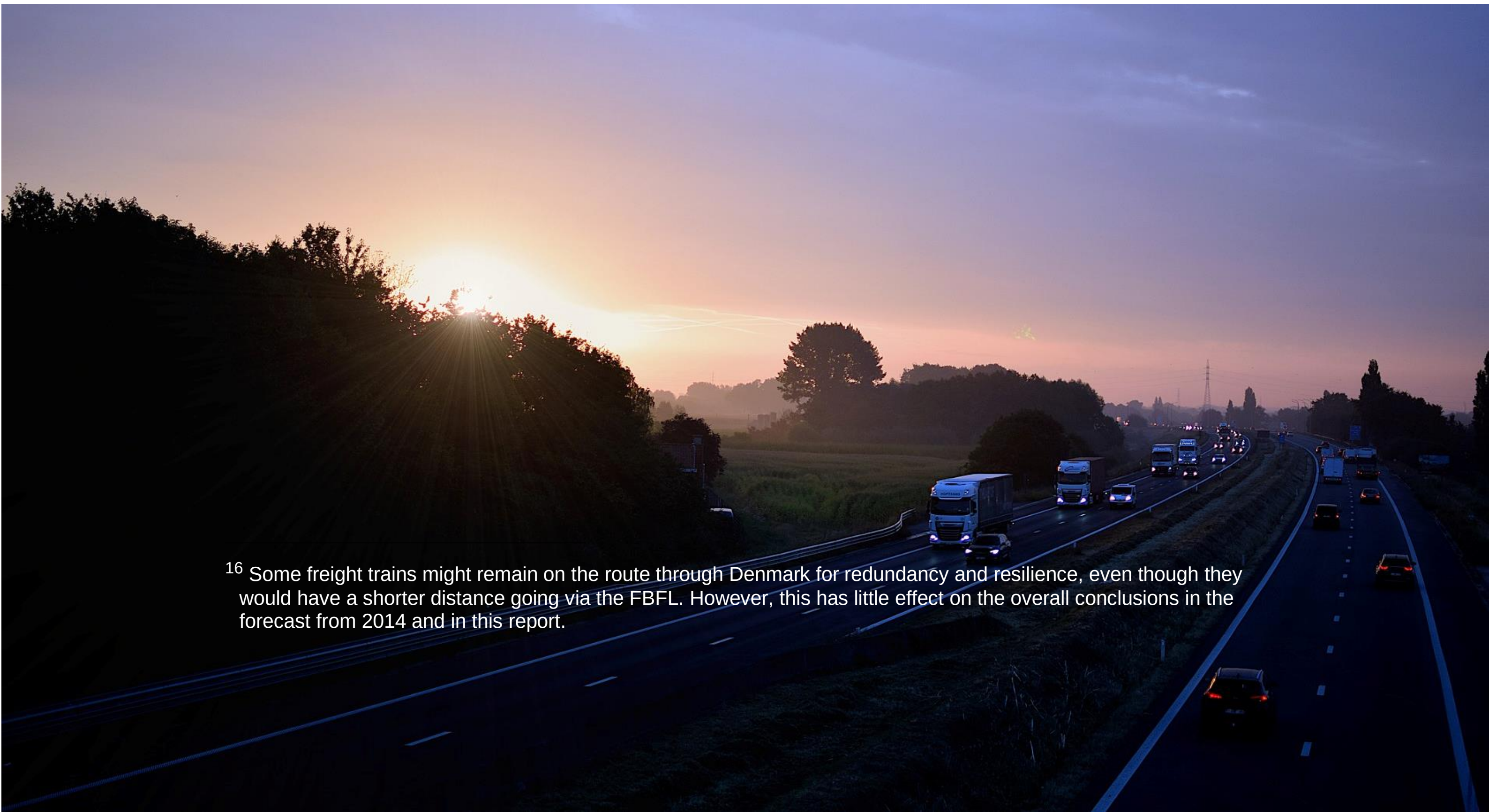
[15] Based on an average weight of 724 tonnes per train and 255 operating days per year.

Denmark, while the transfers from other routes and transport flows are small, see Table 9.

Table 9. A major part of railway volumes on the FBFL in 2022 will come from existing volumes through and to/from Denmark, according to the forecast from 2014. A small part is transferred from other routes and modes. Source: Intraplan and BVU 2014 p.155.

Link	Without the FBFL (tonnes)	With the FBFL (tonnes)	Change (tonnes)	Relative change
Great Belt fixed link	7 973 000	0[16]	- 7 973 000	-100 %
Railway ferries Southern Sweden-Germany	755 000	573 000	-182 000	-24 %
Fehmarn Belt Fixed Link	-	8 320 000	8 320 000	-
Total	8 728 000	8 893 000	165 000 (modal shift from road)	2 %

Of 8.3 million tonnes transported by rail on the FBFL, 98 % stems from existing rail transport, either to/from or through Denmark or via railway ferries. 165 000 tonnes are estimated to move from road to rail. The average load for trucks in general is approximately 15.3 tonnes in the corridor (Intraplan & BVU 2014 p.76). This means that around 11 000 truckloads will move to rail freight transport. The net reduction of road freight volumes on the ferry links between Norway/Sweden and the rest of the European Continent is 40 000 trucks (Table 10).



[16] Some freight trains might remain on the route through Denmark for redundancy and resilience, even though they would have a shorter distance going via the FBFL. However, this has little effect on the overall conclusions in the forecast from 2014 and in this report.

Table 10. Forecast of the number of trucks on different ferry lines in 2022 affected by the FBFL and actual flows in 2011. Source: Intraplan and BVU 2014 p.81, p.153.

Route[17]	1 000 trucks in 2011	1 000 trucks without the FBFL in 2022	1 000 trucks with the FBFL in 2022	Change (1 000 trucks)	Relative change (%)	Share of total loss
Puttgarden-Rödby	366	508	555	47	9.3 %	
Rostock-Gedser	91	139	131	-8	-5.8 %	
Travemünde-Trelleborg	217	319	308	-11	-3.4%	28%
Travemünde-Malmö	206	289	279	-10	-3.5%	25%
Kiel-Gothenburg	85	100	98	-2	-2.0%	5%
Kiel-Oslo	42	44	43	-1	-2.3%	3%
Rostock-Trelleborg	262	407	395	-12	-2.9%	30%
Sassnitz-Trelleborg	15	17	16	-1	-5.9%	3%
Swinoujscie-Ystad	56	73	71	-2	-2.7%	5%
Swinoujscie-Trelleborg	32	43	42	-1	-2.3%	3%
Total		1 292	1 252	-40	-3.1 %	100 %

It is not apparent where the cargo from those trucks 40 000 trucks will end up. Intraplan and BVU (2014 p.153) state that 10 000 vehicles will cross the Öresund. Railway will gain cargo from 11 000 lorries as shown above. There might also be transfers between the ferry links and the Öresund Fixed Link. Still, about 19 000 trucks are “missing”, carrying close to 600 000 tonnes of goods per year, slightly more than three freight trains per day.

[17] Links with no change have not been included.

3.3 Analysis

Intraplan and BVU (2014) predicted that 98 % of future railway volumes on the FBFL are transferred from the Great Belt Fixed Link and the ferry lines. The forecast from 2014 expected those volumes to be 8.2 million tonnes.

Table 11 shows the existing railway volumes transferred to the FBFL if it had opened in 2022. They add up to 6.9 million tonnes, meaning that actual development for rail transport has been weaker than expected. The actual development until today is approximately 1.3 million tonnes “behind” the forecast from 2014. This equals about seven freight trains per day.[18]

The actual development until today is approximately 1.3 million tonnes “behind” the forecast from 2014.

Table 11. A major part of railway volumes on the FBFL will come from existing volumes through and to/from Denmark. A small part is transferred from other routes and modes. Sources: Intraplan and BVU 2014; Danmarks statistik tables BANE3, BANE9; Trafikanalys Sjötrafik.

Link	Mode	Relative change with the FBFL	Average volume per year 2017-21 (tonnes)[19]	Volumes with the FBFL “today”
Great Belt fixed link	Railway	-100 %[20]	6 730 000	6 730 000
Trelleborg-Rostock	Ferry – railway	-24 %	810 000	190 000
Fehmarn Belt Fixed Link	Railway	-	-	6 920 000

However, actual volumes reached 7.6 million tonnes in 2018 (Figure 14). The same year, transit volumes were 6.7 million tonnes, in line with the 2014 forecast (Figure 13).

[18] Using an average weight of a freight train of 724 tonnes (Trafikstyrelsen 2023 p.15) and 255 operating days per year (Intraplan and BVU 2014).

[19] By calculating the average, yearly volume over a period of 5 years, the effect of temporary fluctuations is reduced.

[20] Referring to transit flows through Denmark plus 50 % of Danish international transports excluding Sweden and Norway. The reason for only including 50 % of Danish international transport flows is that Western Denmark will to a large extent use the existing railway to/from Continental Europe.

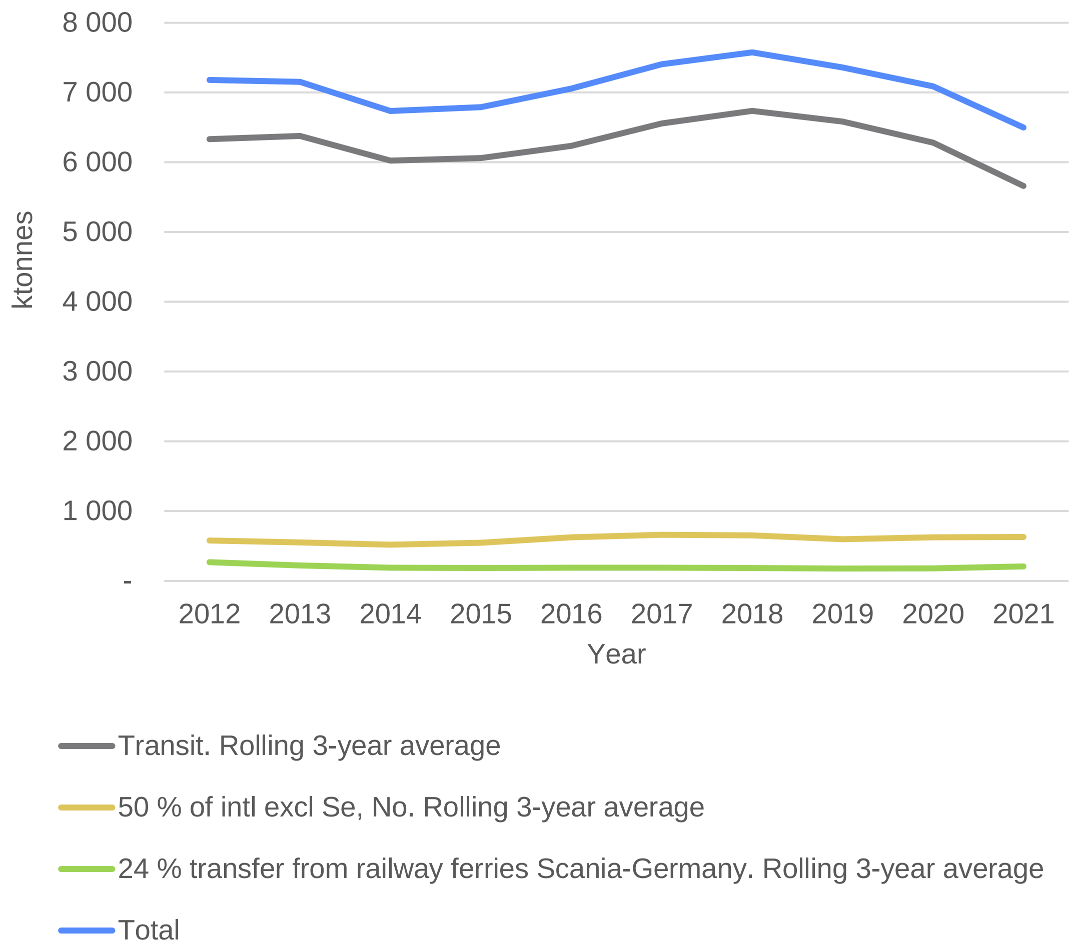


Figure 14. If the FBFL had opened in 2018, 7.6 million tonnes would have been shifted from existing railway routes. Sources: Danmarks statistik tables BANE3, BANE9; Trafikanalys Sjötrafik.

During the last years, development has weakened. This is also confirmed by looking at railway volumes on the fixed link across Öresund … the number of freight trains in 2020 and 2021 have had negative growth

During the last years, development has weakened. This is also confirmed by looking at railway volumes on the fixed link across Öresund, see Figure 15. The number of freight trains in 2020 and 2021 have had negative growth. On the other hand, when comparing the first eleven months of 2022 with 2021, growth has been 23 % (Öresundsbrokonsortiet/Trafikverket 2022). Transit volumes through Denmark increased by 9 % from 2021 to 2022 (Danmarks statistik Table BANE9A). Part of the increase is explained by the decision by Swedish rail freight operator Green Cargo to move about 7 000 rail wagons from the railway ferries to the Öresund Fixed Link and the route through Denmark (Dagens Logistik 2021).

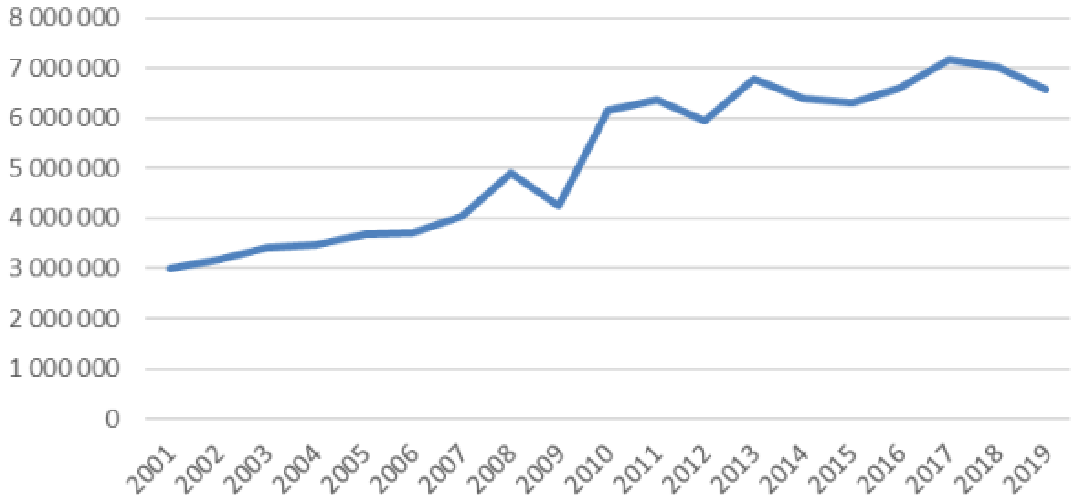


Figure 15. Development of railway volumes on the Öresund Fixed Link. Source: Trafikverket in Ramboll and MOE Tetraplan 2020 p.23.

When transport volumes are smaller than expected, it can often be attributed to weaker growth of GDP, foreign trade, or loss of volumes to other routes and/or transport modes. GDP has grown respectably in all countries every year from 2010 to 2021 with the exception of 2020, when all EU-countries except Ireland experienced negative growth (Europaportalen 2023). The same goes for trade flows in the corridor. Hence, the loss of volumes might be caused by the pandemic and it effects. However, the explanation can also be found in specific events causing problems for rail transport through Denmark. Figure 16 shows transit and international volumes on a quarterly basis.

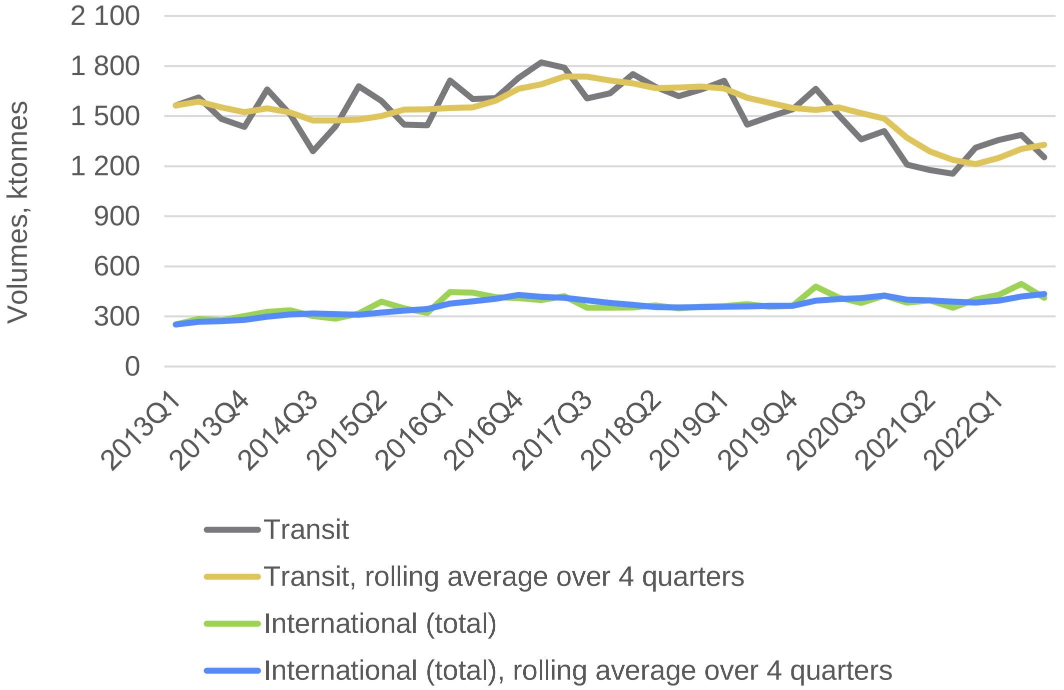


Figure 16. Railway volume per quarter. Source: Danmarks statistik, Table BANE9A.

The decline from 2019 is partly explained by a fatal accident on the Great Belt railway in January 2019. Transit flows were reduced by close to 8 % compared to 2018 due to safety regulations. During 2020, there was a small decline. In early 2021, after another incident, further safety restrictions were issued by the Danish Civil Aviation and Railway Authority, including a minimum gross weight of 14 tonnes for semi-trailers being transported by railway across the Great Belt (Trafikstyrelsen 2021). As a result, volumes declined by close to 20 % compared to 2020. Some goods were instead stuffed in containers, some were shifted to the railway ferries Trelleborg-Rostock and trucks. Still, in September 2021, the main rail freight company in Sweden, Green Cargo, declared that they would stop using the railway ferries and move their around 7 000 wagons to the fixed link across the Öresund. The reason was, according to the company, both shorter lead times and reduced costs. Hence, the number of railway wagons on the ferries declines from around 20 000 per year to 13 000 (Dagens Logistik 2021). As a result, transit volumes on rail through Denmark increased by almost 10 % in 2022.

The explanation that a part of the decline of railway transit through Denmark, and Danish international transports to/from Denmark, is due to the imposed safety restrictions is supported by a comparison of railway volumes in the STRING countries, Figure 17. The mostly downward sloping curve in Denmark from 2019 to mid-2021 is not reflected in the general development in the other countries.

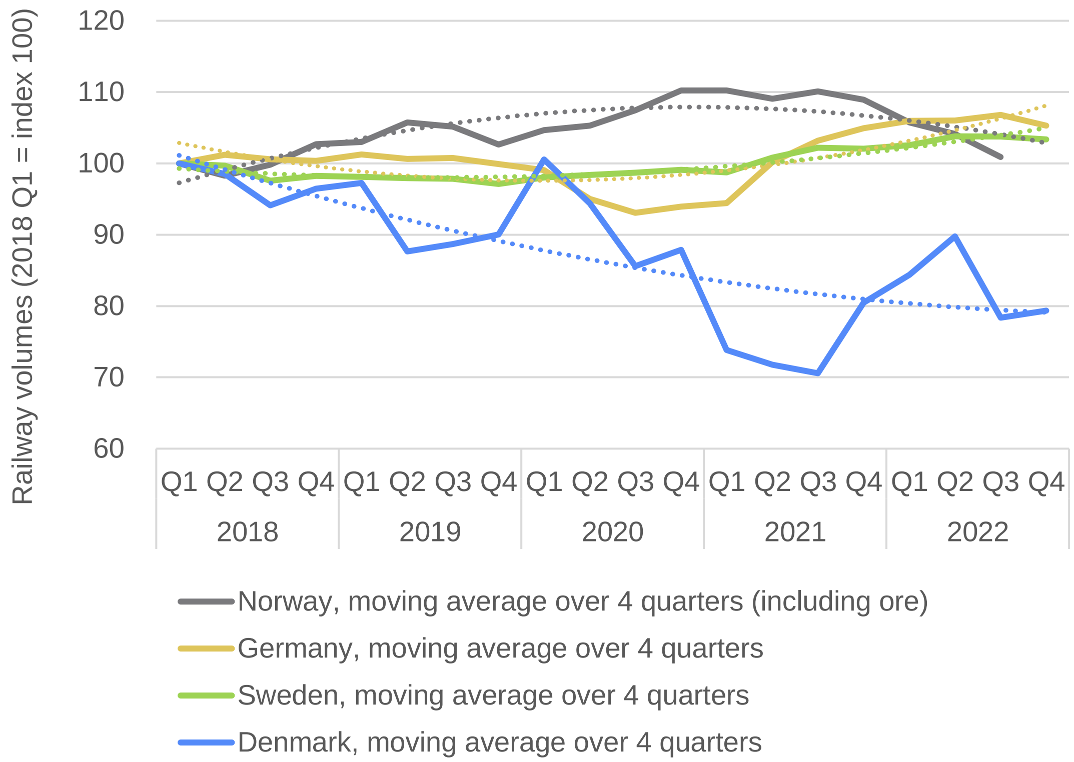


Figure 17. Development of railway volumes from 2018. Moving average over four quarters. Q1 2018 is index 100. Trend lines are second-degree polynomic. Sources: Danmarks statistik Table BANE9A; Statistisches Bundesamt Table 46321-0002; Statistisk sentralbyrå Table 13482; Trafikanalys Järnvägstrafik.

Also, the ferry lines have had a rather strong development during the same period, which can be seen in Figure 18.

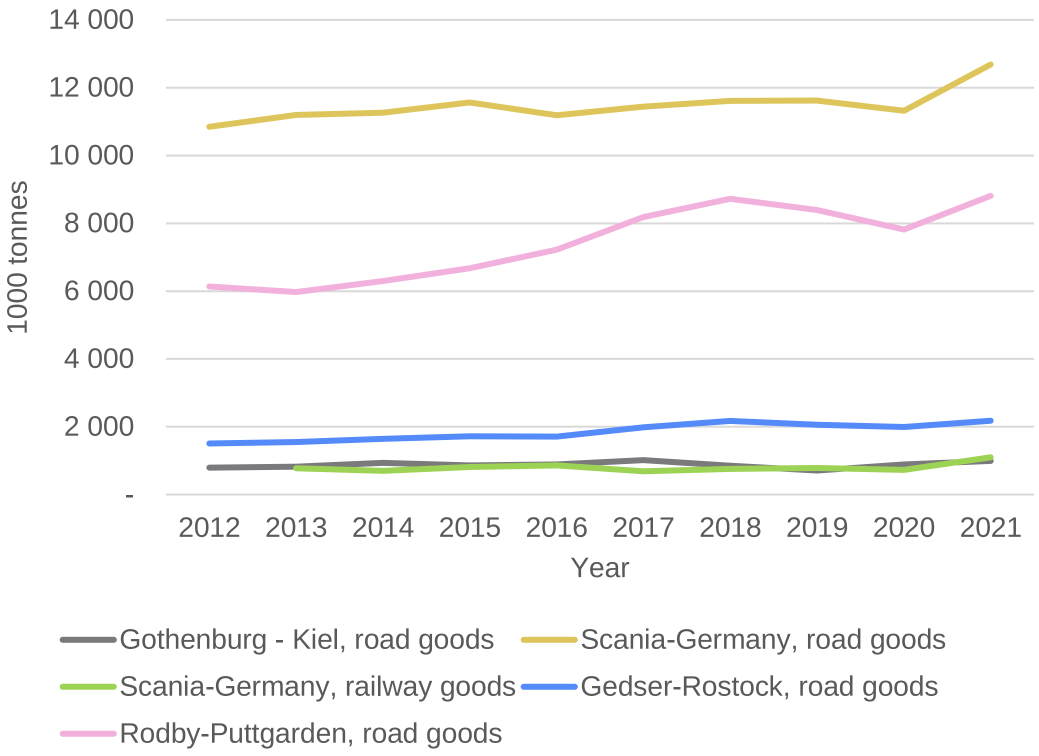


Figure 18. The development of ferry lines 2012-2021. Sources: Trafikanalys Sjötrafik; Danmarks statistik Table SKIB32.

The transfer from the road to rail freight transport is 165 000 tonnes per year in the forecast from Intraplan and BVU (2014). This is obviously not very much. The effect will be discussed from a logistics perspective in chapter 5, but the relative size seems reasonable when compared to other transport models. TØI and SITMA AS (2019) analyse the effect of the FBFL on Norwegian rail freight. The result is an increase of 100 000 tonnes, about 1 % of Norwegian rail volumes in 2020 excluding ore (TØI 2022 p.III). Sweco (2023a) identifies an increase of railway volumes on the fixed link across Öresund with 715 000 tonnes in 2040 thanks to the FBFL, but this figure includes potential shifts from the railway ferries Trelleborg-Rostock.

There are also other studies focusing on the systems perspective, the combined effect of several improvements in the railway sector. For example, in an ambitious study of the possibility of modal shifts, Trafikverket (2021a p.44) states that the FBFL together with the new signalling system ERTMS could increase transport work in Sweden by 1-2 billion tkm, equal to a relative increase of 4-7 %. This will be further discussed in chapter 5.

The figure 165 000 tonnes should be put into perspective, although it is not quite clear exactly where the volumes come from. However, four ferry lines account for 86 % of the total reduction of road transport from ferries to the FBFL (Table 12). It seems reasonable to assume that those four ferry lines are losing volumes both to road and railway.

Table 12. Four ferry lines (marked in bold text) account for 86 % of losses to the FBFL. Source: Intraplan and BVU 2014 p.81, p.153.

Route[21]	1 000 trucks in 2011	1 000 trucks without the FBFL in 2022	1 000 trucks with the FBFL in 2022	Change (1 000 trucks)	Relative change (%)	Share of total loss
Rostock-Gedser	91	139	131	-8	-5.8 %	17 %
Travemünde-Trelleborg	217	319	308	-11	-3.4%	23 %
Travemünde-Malmö	206	289	279	-10	-3.5%	21 %
Kiel-Gothenburg	85	100	98	-2	-2.0%	4 %
Kiel-Oslo	42	44	43	-1	-2.3%	2 %
Rostock-Trelleborg	262	407	395	-12	-2.9%	25 %
Sassnitz-Trelleborg	15	17	16	-1	-5.9%	2 %
Swinoujscie-Ystad	56	73	71	-2	-2.7%	4 %
Swinoujscie-Trelleborg	32	43	42	-1	-2.3%	2 %
Total	1 006	1 431	1 252	-48	-3.4 %	100 %

Therefore, the actual development of those four ferry lines is compared to the forecast from 2014, see Table 13. The ferry line Rödby-Puttgarden is also included. As can be seen, Rostock-Gedser and Rödby-Puttgarden have come close to the forecast from 2014. On the contrary, the Sweden-Germany ferries have experienced growth, but not at the levels assumed in the forecast. The explanation is most likely that the fixed link across the Öresund has won market shares.

[21] Links with no change has not been included.

Table 13. Comparison between the forecast from 2014 and actual development. Sources: Intraplan and BVU 2014 p.82, p.153; Trafikanalys Sjötrafik; Danmarks statistik Table SKIB32.

Route	1 000 trucks in 2011	1 000 trucks without the FBFL in 2022 (forecast)	1 000 tonnes in 2011 (actual)	1 000 tonnes in 2021 (actual)	Change 2011-2021 in the forecast (%, trucks)	Change 2011-2021 actual (%, tonnes)
Rostock-Gedser	91	139	1 524	2 178	53 %	43 %
Travemünde-Trelleborg	217	319	3 424	3 563	47 %	4 %
Travemünde-Malmö	206	289	3 406	3 960	40 %	16 %
Rostock-Trelleborg	262	407	4 235	5 162	55 %	22 %
Total	776	1 154	13 790	14 863	49 %	8 %
Rödby-Puttgarden	366	508	6 057	8 811	39 %	45 %

As can be seen in Table 13, road freight volumes on the ferry lines Rödby-Puttgarden and Gedser-Rostock have increased by approximately 45 % between 2011 and 2021, resulting in an annual growth rate of 3.2 %. Intraplan and BVU (2014 p.153) estimate that close to 92 % of future road freight volumes on the FBFL will come from the existing ferry line Rödby-Puttgarden.

3.4 Conclusions – Previous forecasts and actual development

Existing rail freight volumes through and to/from Denmark or via ferries between Southern Sweden and Germany will make up 98 % of the volumes on the FBFL.

According to the forecast from 2014 by Intraplan and BVU, existing rail freight volumes through and to/from Denmark or via ferries between Southern Sweden and Germany will make up 98 % of the volumes on the FBFL. Only 2 % of additional freight volumes will transfer from the road. This will be discussed in detail later in the report, but the general conclusion regarding the small modal shift from the 2014 forecast seems reasonable and is supported by the results from other transport models (TØI and SITMA AS 2019; Sweco 2023a). The potential rail freight volumes in the corridor will also be limited by German railway bottlenecks and constraints, but this will be commented later in chapters 5 and 6.

The forecast from 2014 lowered expectations of freight development to a more realistic level relative to the prognosis from 2002. The actual development has been even weaker than the main scenario from 2014 though, resulting in a "deficit" of about 1.3 million freight tonnes today. This equals seven freight trains per day.[22]

Still, during the period since 2014, the volumes have been approximately 0.7 million tonnes higher and hence followed the 2014 forecast until 2018. The decline from 2019 seems partially due to the negative effects of the pandemic, partially to railway transport restrictions in Denmark, following the accident on the Great Belt Fixed Link in January 2019.

Road freight volumes on the ferry lines Rödby-Puttgarden and Gedser-Rostock have increased by approximately 45 % between 2011 and 2021, resulting in an annual growth rate of 3.4 %. Intraplan and BVU (2014 p.153) estimate that close to 92 % of future road freight volumes on the FBFL will come from the existing ferry line Rödby-Puttgarden. Current volumes on the ferry line are close to 9 million tonnes, clearly surpassing the forecast for 2025 of 6.9 million tonnes after the opening of the FBFL (Intraplan and BVU 2014 p.165).

As stated, the modest transfer of freight from road to rail is in accordance with other transport models. In the scenarios in the next chapter, the original estimate of 165 000 tonnes of transferred cargo (Intraplan and BVU 2014), will be allocated to the top four ferry lines in Table 13 based on their relative traffic volumes. This will create an *indicator* to get an idea of the volumes possibly transferred thanks to the FBFL. In 2011, the road volumes were 13.8 million tonnes. The number of trucks was expected to increase with 49 %, equal to ~20 million tonnes. Hence, the indicator for transfer from road volumes on the ferries to railway is 0.8 % of the volumes of the four ferry lines (165 000 tonnes divided by 20 million tonnes equals about 0.8 %).

[22] Using an average weight of a freight train of 724 tonnes (Trafikstyrelsen 2023 p.15) and 255 operating days per year (Intraplan and BVU 2014). About 30 freight trains cross the Öresund Fixed Link each day (Öresundsbrokonsortiet/Trafikverket 2022).

4. Scenarios for freight transport on the Fehmarn Belt Fixed Link

This chapter presents scenarios for the freight transport volumes on the FBFL. It also compares these scenarios with EU targets and discusses factors that could increase or decrease rail freight volumes.

4.1 Rail – Four scenarios with their assumptions

The study at hand uses four scenarios to illustrate possible future developments. By constructing the scenarios differently, they provide a methodological advantage and illustrate the uncertainties involved. The four scenarios are presented in Table 14, including their purposes.

Table 14. Four scenarios for future rail volumes on the Fehmarn Belt Fixed Link.

Scenario	Description	Purpose
Rail: Average of National Forecasts	Calculation of an average of national forecasts, weighted by the most important rail freight relations, based on volumes. The growth rate is applied on current land-based rail volumes. The volumes on the railway ferries are assumed to transfer to land and form a part of the growth of the land-based volumes.	This scenario makes use of national forecasts, considering for instance prognoses of demography, economic development, and trade. The scenario illustrates a development with growing rail volumes.
Rail: History High	Linear projection of the historical development 2010-2021, combined with effects of the FBFL according to the 2014 forecast (Intraplan and BVU 2014).	This scenario illustrates a development with growing rail volumes.
Rail: History Low	Linear projection of the historical development 2012-2021, combined with effects of the FBFL according to the 2014 forecast (Intraplan and BVU 2014).	This scenario illustrates a development with declining rail volumes.
Rail: Weak Competitive-ness	Projection of the historical development 2010-2021 based on a more advanced mathematical trend analysis, combined with effects of the FBFL according to the 2014 forecast (Intraplan and BVU 2014).	This scenario illustrates a development with severely declining rail volumes, a “worst case” for the railway.

The scenarios are compared to EU targets for railway growth. The assumptions for the four scenarios are presented in Table 15.

Table 15. Assumptions for the four scenarios.

	Scenarios History High, Low and Weak Competitiveness. Projecting historical development + the FBFL	Average of National Forecasts
Development of population, GDP, trade, etc	Historical development of the impact of these parameters is implicitly included.	National forecasts include prognoses of these parameters.
Supporting measures included (incentives, legislation, etc)?	Historical measures and their effects are implicitly included. No future measures are included.	Historical measures are included. Future, decided measures are included, but only partially harmonized between countries.
Infrastructure capacity	Capacity constraints is an important result of the analysis and are partially included in all scenarios. Constraints are probably important already in scenarios 1 and 2.	
Energy prices, operating costs	Historical prices and costs and their effects are implicitly included. Future expectations are not included in the scenarios but are discussed in the study.	Historical prices and costs and their effects are implicitly included. Assumptions about future costs are included, but only partially harmonized between countries.
Green Cargo left Trelleborg-Rostock in 2022 (7 000 wagons moved to the fixed links)	Included.	Not included.
Ferry lines Denmark-Germany	Whether the ferry line between Rödby and Puttgarden will remain in operation is a genuine uncertainty. Also, the fares might be reduced and/or the frequency increased on the Gedser-Rostock ferry line. This will have a larger impact on road transport but might also affect the chances of a modal shift to rail.	

The historical development of population, GDP, trade, and other macroeconomic aspects are included in all scenarios, and the scenario Average of National Forecasts also contains national prognoses of these aspects.

An underlying assumption for all scenarios is that population, productivity, and trade will have a positive development in the STRING countries during the period, although there will surely be recessions as well. The assumption is supported by national forecasts as well as prognoses from organizations like OECD (ITF/OECD 2021).

A positive economic development has historically driven demand for transport. One question is therefore if economic growth will be decoupled from demand for freight transport. This is sometimes suggested by experts as part of climate mitigation (ITF/OECD 2021 p.25). The main explanations for such a development are that economic growth is to a higher extent driven by investments in knowledge, hence increasing the value of goods but not the weight, the increasing importance of the service sector, digitalization, and investments to actively reduce materials in products, thus reducing the weight. However, at the EU-level the correlation between GDP growth and freight transport remains strong, see Table 16.

Decoupling of GDP growth and freight transport is also counteracted by recent post pandemic trends of reallocating production from Southeast Asia to, firstly, Eastern and Central Europe, secondly, Western Europe (Business Sweden 2022 p.2) and by reindustrialization in Northern Scandinavia. It should not be excluded that the correlation between economic growth and freight transport will be weaker, but in this study, demand for freight transport is expected to grow during the period. This assumption is also reflected by national and international forecasts (ITF/OECD 2021 and others).

Table 16. Annual growth rates in EU-27. Sources: EC 2022 p.21; Sweco.

Annual growth rates EU-27	1995-2020	2000-2020	2019-2020
GDP (2005 prices and exchange rates)	1.4 %	1.0 %	-5.9 %
Freight transport work (tkm)	1.2 %	0.9 %	-3.6 %
Elasticity (growth of transport work/growth of GDP)	0.85	0.90	0.61

Regarding any impacts of new incentives and legislation, these are not included in the scenarios History High, Low and Weak Competitiveness, but will be discussed as part of the analysis. Decided measures are partly included in scenario Average of National Forecasts.

Typically, transport volumes are considered to be independent of infrastructure investments. Put in other words, no single improvement of the infrastructure is considered important enough to reduce transport costs enough to increase volumes of trade. Transport volumes can hence be assumed to be exogenously given when analysing a specific infrastructure project. Hence, the infrastructure project “only” affects the choice of transport route and transport mode. Still, it could be argued that the reduced transport costs could influence trade volumes in the form of so-called wider economic impacts. On behalf of the Femern A/S, Intraplan (2019) has studied the magnitude of these dynamic effects on freight transport. The conclusion is that rail volumes are marginally increased by 41 000 tons, corresponding to an increase of 0.4 % relative to the main prognosis of 9.46 million tons by 2030.[23]

[23] When it comes to passenger traffic, the impact is much more important, increasing volumes by more than 20 %. For trucks, dynamic effects add slightly more than 5 % to the volumes of the main prognosis (Intraplan 2019 p.14).

Infrastructure capacity is part of the analysis, see chapter 6. KombiConsult and Ramboll (2021) have shown that there are several geographies and links in the STRING corridor where there are obvious problems (the Hamburg region, Oslo-Gothenburg, for instance.)

Energy prices and fuel costs are important factors when choosing a transport mode. Assumptions about future developments are included in scenario Average of National Forecasts, but not for the scenarios based on historical development.

4.2 Rail – Scenario Average of National Forecasts

This scenario is calculated as an average of national forecasts for rail transport in the STRING corridor and adjoining destinations.

National forecasts will, to some extent, reflect political ambitions regarding the transport sector. They also reflect the general competitiveness of the railway compared to other modes of transport, taking into consideration political decisions and infrastructure investments that might influence transport mode choices.

Admittedly, it is a highly simplified approach to apply forecasts for the national level on a specific corridor and even links within that corridor. Conditions also vary between countries, for instance the relation between domestic and international transport.

The forecasting approach also varies significantly between the countries, for example related to their treatment of domestic versus international transport.

The forecasts are not harmonized between countries regarding the time period. Germany will publish a long-term forecast later in 2023 using the traditional method applied, but in March 2023 a forecast was presented, using a new, developed method (Intraplan and TTS Trimode 2023). Danish authority Vejdirektoratet (2023) has assisted this study by extracting a forecast for Danish, international rail transport from 2020 to 2040. Table 17 presents forecasts for railway transport in Norway, Sweden, Denmark, and Germany. For Germany, the forecast for transport work of CAGR 0.93 % will be used. For Denmark, an annual growth rate of 3 % will be used, based on the forecasts presented in combination with the CAGR for the period 2010-2022.[24]

[24] Admittedly, this reasoning has a certain amount of arbitrariness.

Table 17. Forecasts for railway transport in the STRING-countries.

Country	CAGR, % per year	Unit	Time period	Comment	Source
Germany	0.41 %	Tonnes	2019-2051		Intraplan and TTS Trimode (2023 p.51)
	0.90 %	Tkm	2019-2051		Intraplan and TTS Trimode (2023 p.51)
	1.80 %	Tkm	2010-30	Actual CAGR 2010-22: 1.25 % (tkm) 0.07 % (tonnes)	Bundesministerium für Verkehr und digitale Infrastruktur (2010 Table 17); Statitisches Bundesamt Table 46131-0001
Denmark	2.13 %	Tonnes	2020-2040		Vejdirektoratet (2023)
	2-4 %	Tkm	2017-2029	Danish international. Actual CAGR 2010-2022: 3.56 % (tkm) 1.88 % (tonnes)	Trafik-, Bygge- og Boligstyrelsen (2017 p.62) Danmarks statistik Table BANE1
Sweden	1.55 %	Tkm	2017-2040		Trafikverket (2020)
Norway	1.12 %	Tonnes	2020-2040	Excluding ore	TØI (2022. p.III), Sweco calculations
Öresund fixed link	1.68 %	Tonnes	2019-2040	Forecast in Swedish-Danish study on a fixed link Elsinore Helsingborg from 2021	Sweco calculations based on Ramboll and MOE Tetraplan (2020 p.7, p.22)
FB 2014 forecast	2.4 %	Tonnes	2011-2035		Intraplan and BVU 2014 p.13

Figure 19 shows the largest trade relations between Scandinavia and Continental Europe.

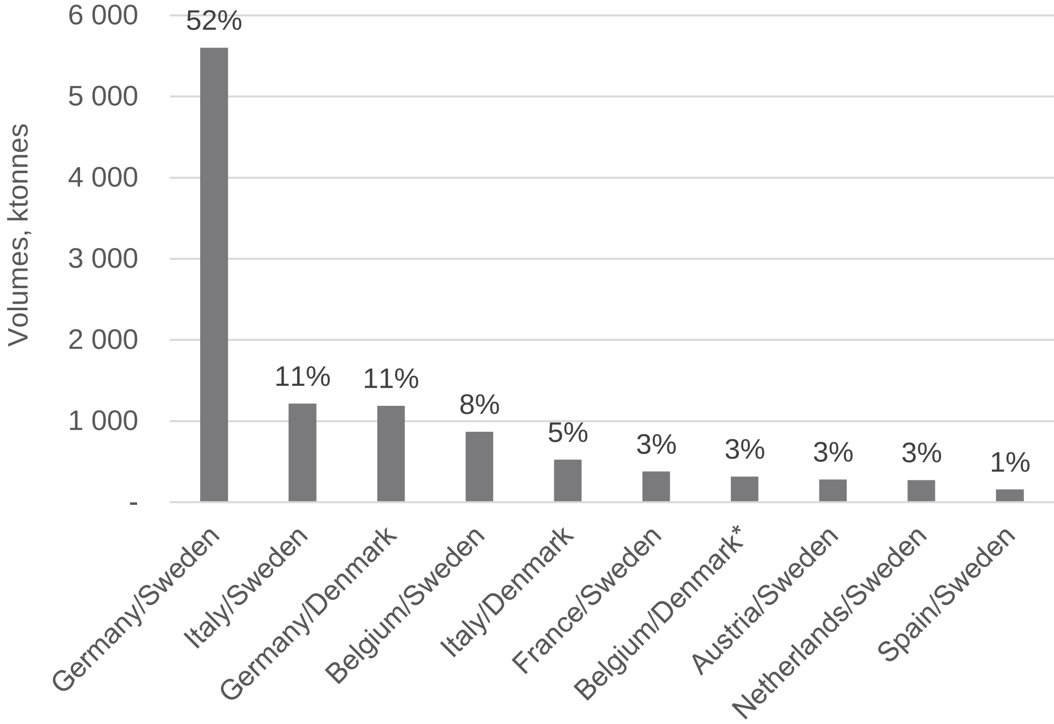


Figure 19. Total railway volumes, moving 3-year average 2021 for the most relevant trade relations between Scandinavia and Continental Europe. Source: Eurostat 2023.
**) Transports from Belgium to Denmark only.*

The national forecasts are combined with the relative weight of the most important trade relations to calculate an average growth rate for railway transport in the corridor and hence across the FBFL (Table 18). For relations where the forecast of one country is not known, the available national forecast is used. This results in a CAGR of 1.67 %, which will be used for the scenario Average National Forecast. As it happens, this growth rate is very similar to one forecast for rail freight on the fixed link across the Öresund, see Table 17 (Ramboll and MOE Tetraplan 2020; Sweco). The growth rate will be applied upon the current land-based rail volumes through and to/from Denmark. The volumes on the railway ferries are assumed to transfer to the Öresund Fixed Link. That transfer forms a part of the growth for the land-based volumes.

Table 18. Calculating an average growth rate based on national forecasts and the relative weight of the largest trade relations.

Trade relation	Forecast country 1	Forecast country 2	Average forecast	Share	Weighted average
Germany-Sweden	0.93 %	1.55 %	1.24 %	52 %	0.64%
Italy-Sweden	-	1.55 %	1.55 %	11 %	0.17%
Germany-Denmark	0.93 %	3 %	1.97 %	11 %	0.22%
Belgium-Denmark	-	3 %	3 %	8 %	0.24%
Italy-Denmark	-	3 %	3 %	5 %	0.15%
France-Sweden	-	1.55 %	1.55 %	3 %	0.05%
Belgium-Denmark	-	3 %	3 %	3 %	0.09%
Austria-Sweden	-	1.55 %	1.55 %	3 %	0.05%
Netherlands-Sweden	-	1.55 %	1.55 %	3 %	0.05%
Spain-Sweden	-	1.55 %	1.55 %	1 %	0.02%
Total				100 %	1.67 %

4.3 Rail – Scenarios History High, History Low and Weak Competitiveness

Three scenarios are based on historical developments of transport volumes.

4.3.1 History High

The first scenario means a projection of the historical development, utilizing the forecast from 2014 for modal and route shifts.

Intraplan and BVU (2014) expected that existing railway volumes on land together with transfers from the railway ferries will make up approximately 98 % of future railway volumes on the FBFL. Figure 20 shows the development of those volumes since the beginning of the 2000s. The curves are smoothed through a moving yearly average over three years. Only half of the Danish international volumes are included to reflect transport to and from Western Denmark on the existing railway.

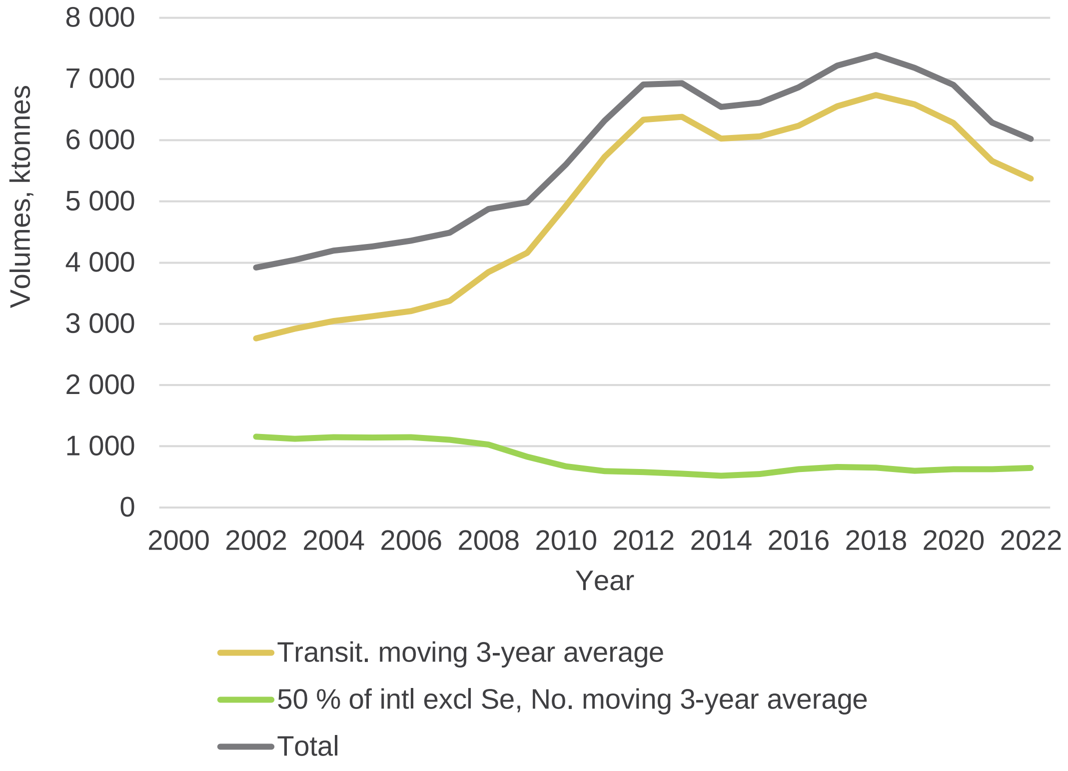


Figure 20. Railway transport through and to/from Denmark are expected to move to the FBFL as it opens. Sources: Danmarks statistik, tables BANE3, BANE9; Sweco.

Figure 20 shows a strong development in transit volumes through Denmark from the year 2000 to 2010. However, this development has been driven by the opening of the fixed link across the Öresund in the year 2000. Since around 2012, volumes have been relatively stable with periods of growth as well as decline.

Historical development from 2010-2021 forms a scenario called History High. Figure 21 shows the development of transit volumes together with volumes on the train ferries between Southern Sweden and Germany. The trend line shows a compounded annual growth rate (CAGR) of 0.84 %, leading to an increase in total volumes from 7 million tonnes in 2010 to 8.2 million tonnes in 2029. This development is of roughly the same size as the Öresund fixed link during 2010-2019, where CAGR has been 1.0 %. This is not surprising, since volumes crossing the Öresund fixed link are to a high degree overlapping with transit flows through Denmark. Looking only at transit flows, the trend line in Figure 21 corresponds to a CAGR of 1.25 %. Danish international transport has zero growth, as shown by the trend line. Railway ferries experience negative growth in this scenario with a CAGR of -7.7 %. Together with the fact that the Swedish rail freight company Green Cargo left the ferries in 2022, this probably means that the railway ferries will stop operating when the FBFL opens in 2029, at the latest.[25] Hence, all remaining freight transport volumes move to the FBFL.

[25] This important drawback for railway corridor redundancy is further discussed in chapter 6.

It is important to highlight a few things about the scenario. First, the trend line is based on a linear regression, resulting in an upwards slope. It is by no means obvious that this trend line is reflecting the actual, underlying development. A polynomic regression results in a trend with a very negative development with volumes being dramatically reduced until 2029. see scenario “Weak Competitiveness”. Second, the trend line gives the impression of continuous growth “forever”, which is not realistic. Still, bearing this in mind, History High forms a long-term positive scenario.

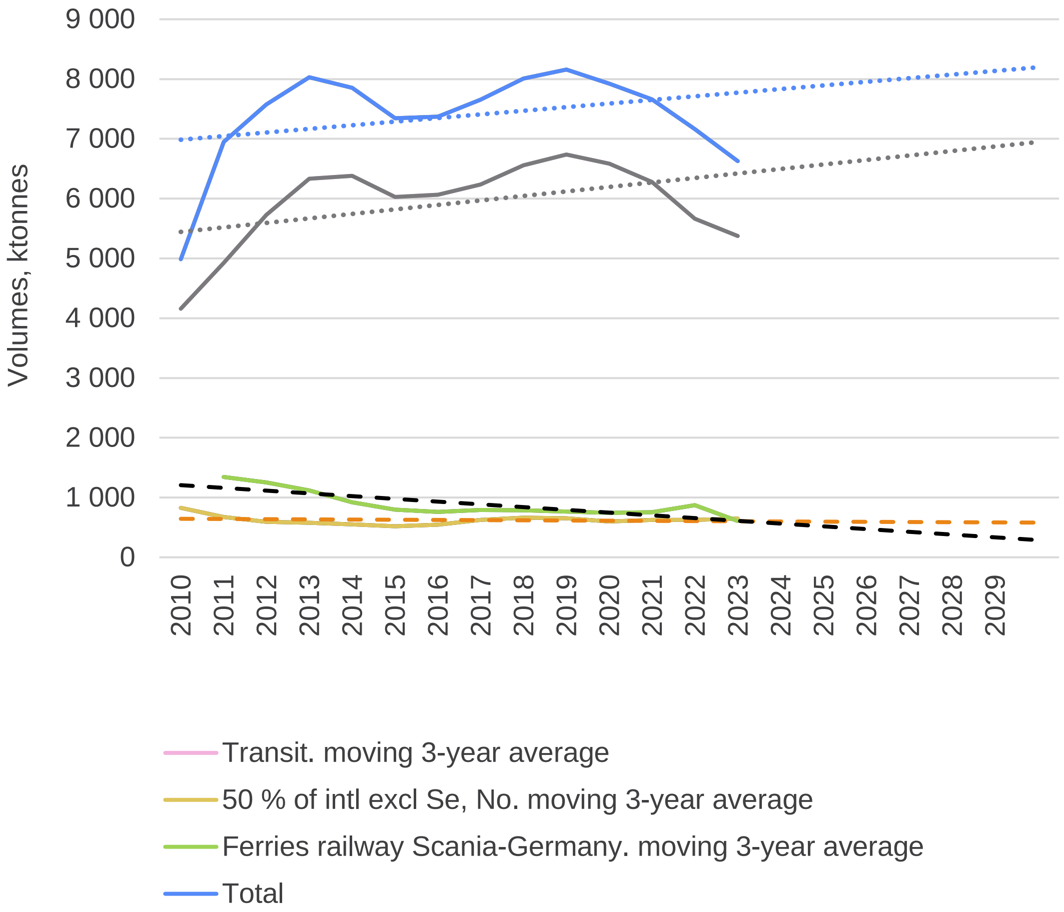


Figure 21. Projection of historical development 2010-2022. Sources: Danmarks statistic Table BANE1, BANE3; Trafikanalys Sjötrafik; Sweco.

Chapter 3.4 introduced an indicator for capturing the potential transfer from road freight volumes on ferries to the FBFL railway. The indicator is 0.8 % of the volumes on the four ferry lines that account for 86 % of expected volume losses according to the forecast from 2014. Therefore, the development of these four ferries routes is analysed in the same way as the railways on land and on ferries. The total volumes are projected to grow by a CAGR 1.2 %.

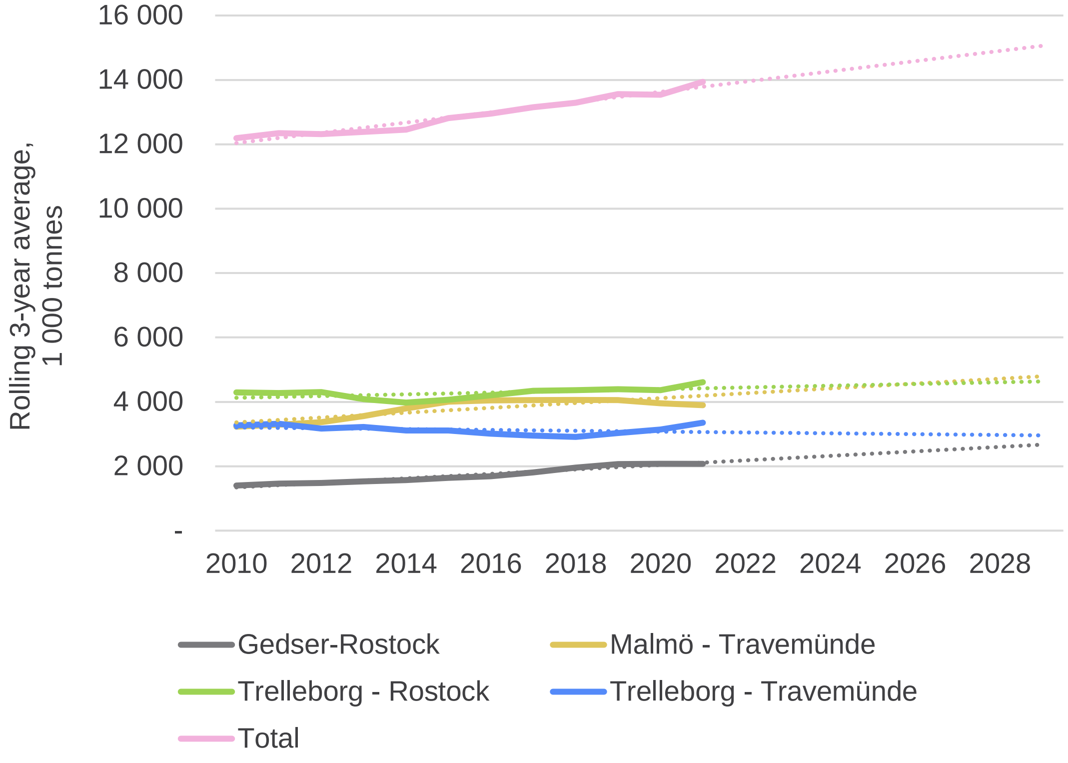


Figure 22. Projection of historical development 2010-2021. Sources: Trafikanalys Sjötrafik; Danmarks statistik, Table SKIB232; Sweco.

Table 19 summarizes the annual growth rates for scenario History High.

Table 19. Growth rates for scenario History High.

Volumes	CAGR (% per year) 2022-2029	CAGR (% per year) 2029-2040	Comment
Transit	1.25 %	1.25 %	In 2022, ~7/20 of the railway ferry volumes transported by Green Cargo moved to land transport through Denmark.
Danish international to/from Eastern Denmark	0	0	
Railway ferries Southern Sweden-Germany	-7.7 %	-	It is assumed that the volumes lost are transferred to the Great Belt Fixed link. When the FBFL opens, all remaining volumes will shift to the FBFL.
Road volumes, ferries	1.2 %	1.2 %	The transfer to the FBFL is calculated with a share of 0.8 % of volumes. The ramp-up time is 3 years.

The growth rate for the cargo volumes moved from road transport and ferries to rail across the FBFL is assumed to remain after the transfer.

4.3.2 History Low

However, it is obvious from the numbers that the development in the last years has not been as favourable. This was also illustrated by the transport development over the fixed link across the Öresund (Figure 15). Although this seems to have been a consequence of the pandemic as well as the restrictions on rail transport through Denmark following the accident on the Great Belt Fixed Link in 2019, there is a need for a second scenario reflecting the difficulties the railway has had to compete with road transport. The scenario is called History Low and is based on linear projections from the period 2012-2021, see Figure 23.

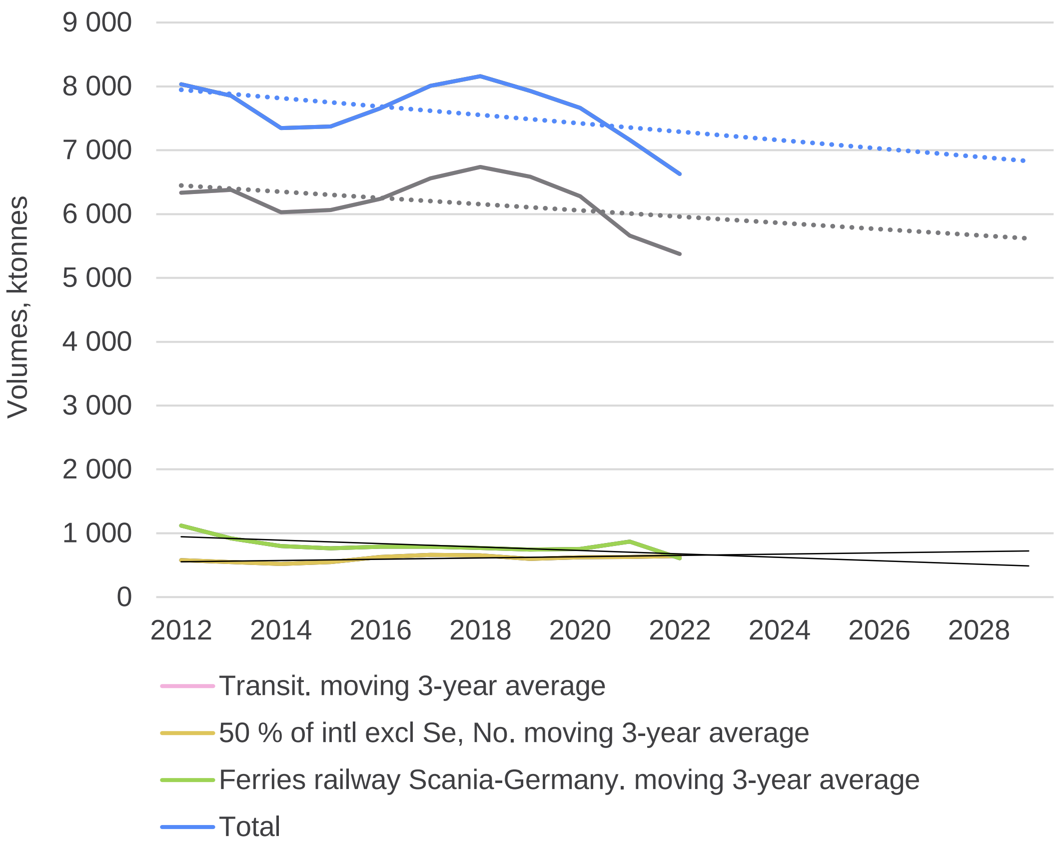


Figure 23. Projection of historical development 2012-22 including trends to 2029. Sources: Danmarks statistik Table BANE1, BANE3; Trafikanalys Sjötrafik; Sweco.

For road freight volumes on ferries, the growth rate is the same as for the period 2010-2022 (Figure 24).

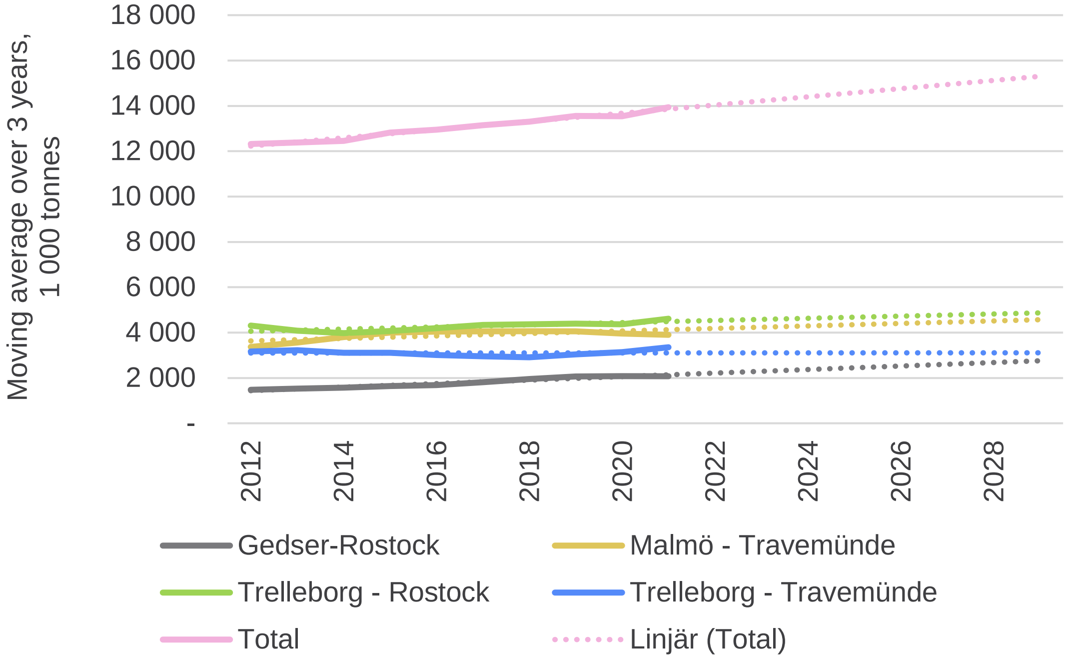


Figure 24. Projection of historical development 2012-21. Sources: Trafikanalys Sjötrafik; Danmarks statistik Table SKIB232; Sweco.

The annual growth rates for scenario History Low are summarized in Table 20.

Table 20. Growth rates for scenario History Low.

Volumes	CAGR (% per year) 2022-2029	CAGR (% per year) 2029-2040	Comment
Transit	-0.7 %	-0.7 %	In 2022, ~7/20 of the railway ferry volumes transported by Green Cargo moved to land transport through Denmark.
Danish international to/from Eastern Denmark	1.7 %	1.7 %	
Railway ferries Southern Sweden-Germany	-4.6 %	-	It is assumed that the volumes lost are transferred to trucks. When the FBFL opens, all remaining volumes will shift to the FBFL railway.
Road volumes, ferries	1.2 %	1.2 %	The transfer to the FBFL is calculated with a share of 0.8 % of volumes. The ramp-up time is 3 years.

The growth rate for the volumes moved from road transport and ferries to rail across the FBFL is assumed to remain after the transfer.

4.3.3 Weak Competitiveness

This scenario is included to highlight the possibility that rail freight transport in the corridor will develop even worse. The scenario therefore serves the purpose of underlining the challenges regarding for instance capacity constraints in the network. It also reflects the problems of the railway to maintain competitiveness compared to road transport. The scenario could be realized by a combination of an accelerating demand for logistics services where rail transport is substandard compared to road transport, together with weak innovation capabilities. From a railway perspective, this scenario is to be considered a "worst case". To illustrate the scenario, Figure 25 shows an extension of a polynomial trend curve for the period 2010-2022, resulting in a CAGR of -5 % for transit volumes.

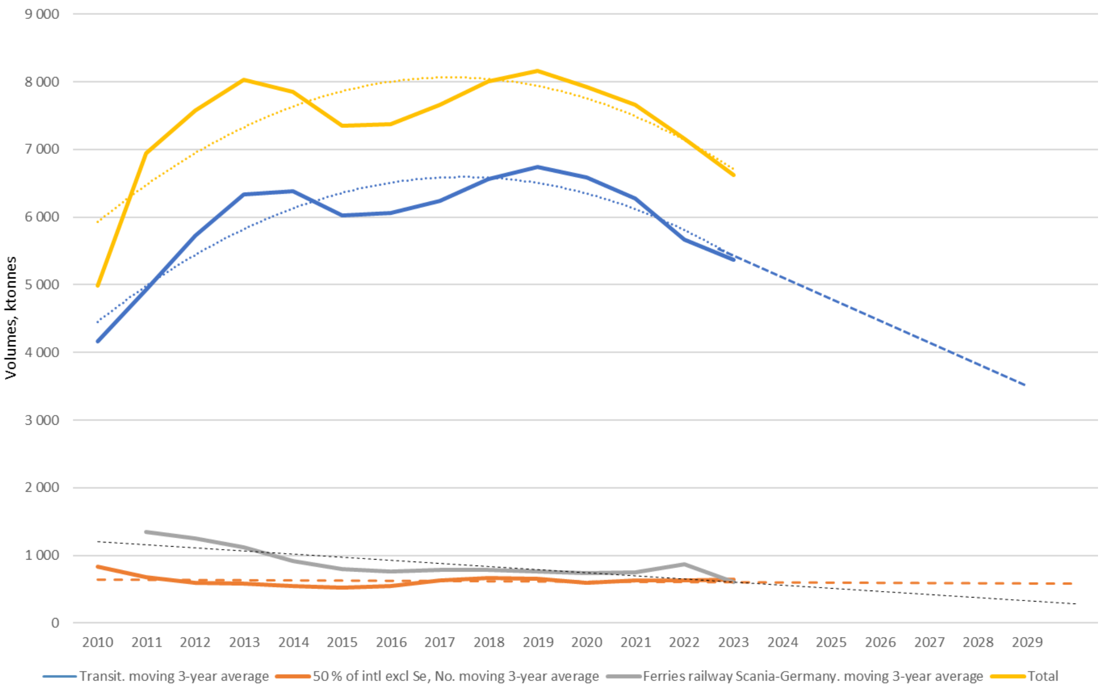


Figure 25. Scenario Weak Competitiveness is based on a projection of a polynomial trend curve of the development 2010-2022. Sources: Danmarks statistik tables BANE1, BANE3; Trafikanalys Sjötrafik, Sweco.

The annual growth rates for the scenario Weak Competitiveness are summarized in Table 21. In the calculations, it is assumed that the FBFL will reduce the negative growth rate to -0.7 % per year, the same as in History Low.[26] It might be a bit counterintuitive that Danish international transport experiences decent growth in this scenario, but it could be considered as a damper of the negative growth rate.

[26] Otherwise, the scenario means that railway transports will be reduced by another 50 % between 2030 and 2040, severely threatening their existence. This is considered too pessimistic, by far.

Table 21. Growth rates for scenario Weak Competitiveness.

Volumes	CAGR (% per year) 2022-2029	CAGR (% per year) 2029-2040	Comment
Transit	-5 %	-0.7 %	In 2022, ~7/20 of the railway ferry volumes transported by Green Cargo moved to land transport through Denmark.
Danish international to/from Eastern Denmark	1.7 %	1.7 %	
Railway ferries Southern Sweden-Germany	-4.6 %	-	It is assumed that the volumes lost are transferred to trucks. When the FBFL opens, all remaining volumes will shift to the FBFL railway.
Road volumes, ferries	1.2 %	1.2 %	The transfer to the FBFL is calculated with a share of 0.8 % of volumes. The ramp-up time is 3 years.

4.4 Rail – EU targets

The European Commission published a white paper on transport in 2011, stating the goal that 30 % of road freight longer than 300 km should shift to railway or waterborne transport by 2030 and more than 50 % by 2050 (EC 2011 p.9).[27] The first target would have meant an increase of railway and inland waterway transport of close to 90 % (Tavasszy and van Meijeren 2011 p.8). This equals a compounded annual growth rate (CAGR) of 3.4 %.

In Norway, the government has had the same ambition as the European Union, to transfer 30 % of goods over 300 km from the road to sea and rail. The Railway Directorate estimates that the transfer would correspond to a doubling of transport volume and transport work compared to 2017 (Jernbanedirektoratet 2019 p.2). That would mean a CAGR of 5.4 %. Currently, the transport authorities in Norway seem determined to abolish that goal, which they do not consider useful and even counterproductive (Transportetatene 2023c p.vi).

In 2020, the European Commission stated a new target to increase rail freight transport by 50 % by 2030 and double it by 2050 compared to 2015 (EC 2020 p.11). This equals a CAGR of 2.7 % until 2030. Over the entire period 2015-2050, the target equals a CAGR of 2.0 %.

[27] Around 11 % of road transports in the EU were over 300 km in 2011 (Tavasszy and van Meijeren 2011 p.7).

Actual development since 2015 has not met the target from 2020. In 2015, transport work was 390.6 billion tkm[28]. In 2020, that number had increased to only 401.2 billion tkm[29] (EC 2022 p.36). Although the effect of the pandemic is to some extent in play here, it means that railway volumes must grow by 3.9 % per year between 2020 and 2030 to reach the target.

Applying the EU target on the transports expected to use the FBFL, mainly coming from existing transit through Denmark and international Danish transport, provides a benchmark for 2030 and 2040, see Table 22.

Table 22. Applying EU targets on the FBFL.

Link	Great Belt Fixed Link in 2015	Change	Total
Average volume per year 2013-15 (tonnes)	6 600 000[30]		6 600 000
EU target + 50 % to 2030		+ 3 300 000	9 900 000
EU target + 100 % to 2050		+ 6 600 000	13 200 000
Increase from 2030		+ 3 300 000	
EU Target 2050 halfway in 2040		+ 1 650 000	11 600 000

It could be noted that the European Rail Freight Operators have an even more ambitious target than the European Commission, to increase railway market share to 30 % in 2030. This would mean a doubling of today's volumes (Rail Freight Forward Coalition 2018 p.13). Such a development equals a CAGR of 6 % per year.

4.5 Road – Scenarios Road History and Road Low

An underlying assumption for both road freight scenarios, just as for the rail scenarios, is that population, productivity, and trade will have a positive development in the STRING countries during the period until 2040.

Intraplan and BVU (2014 p.153) estimate that close to 92 % of future road freight volumes on the FBFL will come from the existing ferry line Rödby-Puttgarden. Road freight volumes on the ferry lines Rödby-Puttgarden and Gedser-Rostock have increased by approximately 45 % between 2011 and 2021, resulting in an annual growth rate of 3.4 %.

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[28] Yearly, average volumes for the period 2013-2015.

[29] Yearly, average volumes for the period 2018-2020.

[30] Referring to transit flows through Denmark plus 50 % of Danish international transports excluding Sweden and Norway. The reason for only including 50 % of Danish international transport flows is that Western Denmark will to a large extent use the existing railway to/from continental Europe.

Current volumes on the ferry line Rödby-Puttgarden are close to 9 million tonnes, clearly surpassing the forecast even for the year 2025, after the opening of the FBFL, of 6.9 million tonnes (Intraplan and BVU 2014 p.165). Depending on the choice of period, CAGR has fluctuated between 3.1 % and close to 6 %. The average CAGR for the periods 2010-21 and 2012-21 is 3.5 %. This forms the basis for the scenario “Road Historical”, in combination with the increase from the opening of the FBFL by about 10 % (Intraplan and BVU 2014 p.152).

Looking at national forecasts on the development of road freight transports, they estimate lower growth rates than observed on the ferry line between Rödby and Puttgarden during the last decade. As a very large part of road transport is considerably shorter than the potential transports via the FBFL, the numbers in Table 23 function more as to give an indication of the level of growth rates in the countries. For the scenario “Road Low”, a CAGR of 1.25 % is used, simply the average of the growth rates in the table. The growth rate is combined with the expected effect of the opening of the FBFL.

Table 23. Forecasts for road freight transport in the STRING-countries.

Country	CAGR, % per year	Unit	Time period	Source/comment
Germany	0.92 %	Tonnes	2019-2041	Intraplan and TTS Trimode (2023 p.51)
	1.36 %	Tkm	2019-2041	Intraplan and TTS Trimode (2023 p.51)
	1.65 %	Tkm	2010-2030	Bundesministerium für Verkehr und digitale Infrastruktur (2010 Table 17)
Denmark	1.1 %	Vehicle km	2020-2040	Vejdirektoratet (2021) Table 9; Sweco calculations Vehicle kilometres by trucks on Danish highways.
Sweden	1.65 %	Tkm	2017-2040	Trafikverket (2020)
Norway	1.0 %	Tonnes	2020-2040	TØI (2022 pp.III-V), Sweco calculations
	1.20 %	Tkm	2020-2040	

4.6 Conclusions – Scenarios for freight transport on the FBFL

In this chapter, a total of six scenarios have been introduced, four for rail freight volumes and two for road freight. Since the modal shift from road freight to rail because of the FBFL is expected to be very small, the scenarios could very well co-exist, as they depend more on the development of trade volumes than on each other.

The four rail freight scenarios are shown in Figure 26 together with EU targets as a benchmark.

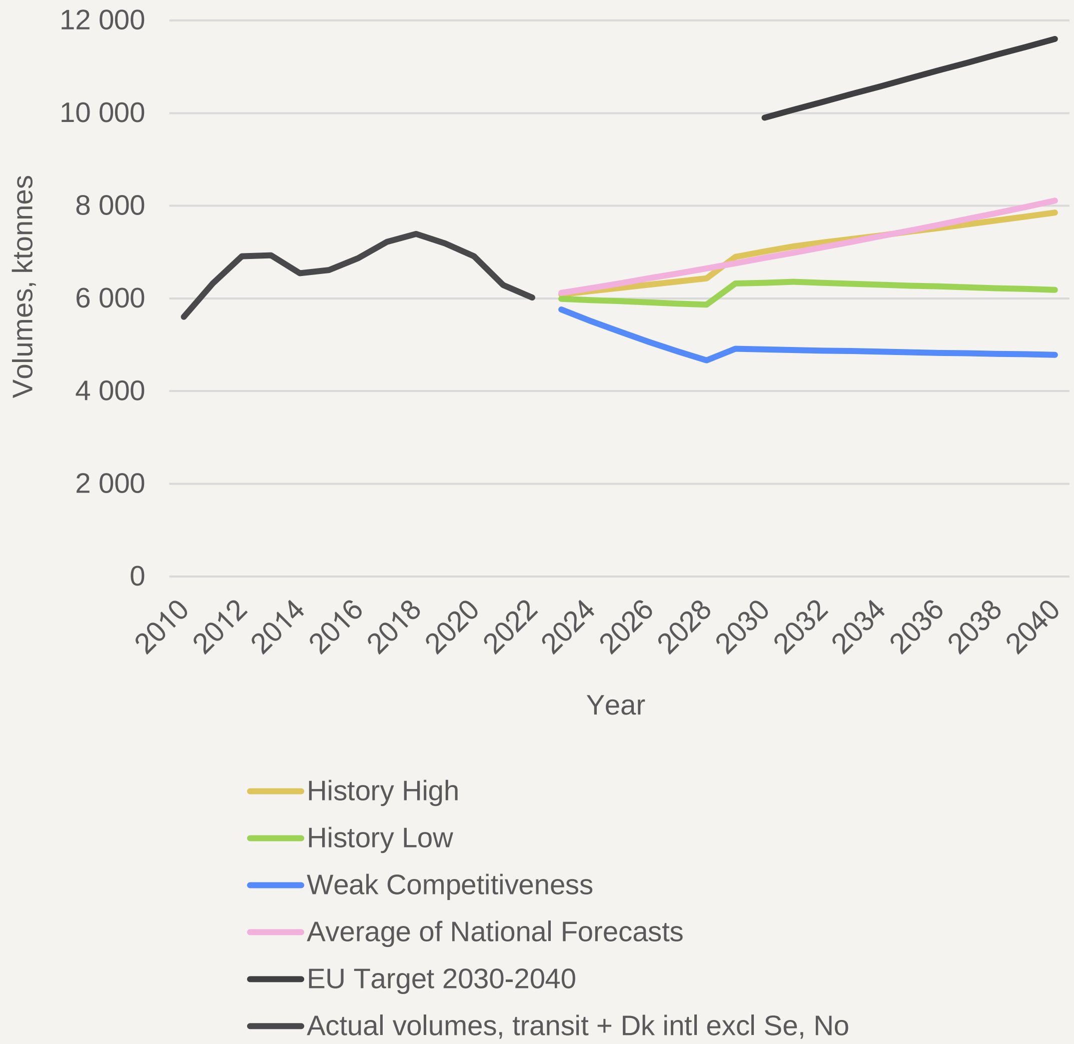


Figure 26. Four scenarios for rail freight volumes on the FBFL and the EU targets as a benchmark.

The four rail freight scenarios are presented in Table 24.

Table 241. Four scenarios for rail freight volumes on the FBFL.

Scenario	Volumes/trains[31]	Year				Change
		2022	2030	2035	2040	2022-2040
Average of National Forecasts	Volumes (Mtonnes)	6.9	6.9	7.5	8.1	18 %
	Trains per day	37	37	40	44	
History High	Volumes (Mtonnes)	6.9	7.3	7.7	8.1	18 %
	Trains per day	37	39	42	44	
History Low	Volumes (Mtonnes)	6.9	6.3	6.3	6.2	-10 %
	Trains per day	37	34	34	34	
Weak Competitive-ness	Volumes (Mtonnes)	6.9	4.9	4.8	4.8	- 30 %
	Trains per day	37	27	26	26	

History High is similar to the Average of National Forecasts. In History High, History Low and Weak Competitiveness, all volumes from the railway ferries are moved to the FBFL as the remaining volumes on the ferries are deemed too small to motivate operations. History Low has a weak development and Weak Competitiveness even more so.

[31] The number of trains are calculated by using the average weight of a freight train in Denmark in 2020, 724 tonnes (Trafikstyrelsen 2023 p.15) and 255 operating days per year (Intraplan and BVU 2014).

The two road freight scenarios are presented in Figure 27, and Table 25.

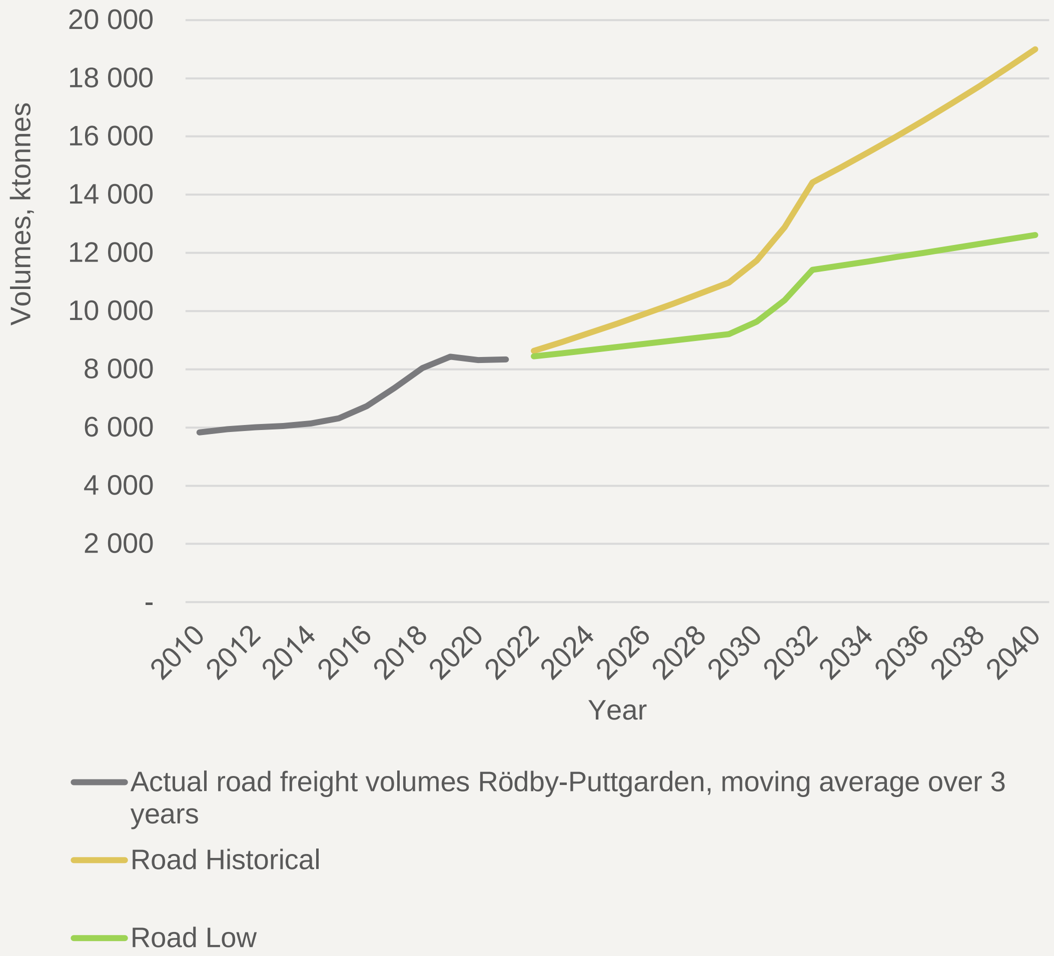


Figure 27. Two scenarios for road freight volumes on the FBFL.

Table 25. Two scenarios for road freight volumes on the FBFL.

Scenario	Volumes/trucks[32]	Year				Change
		2022	2030	2035	2040	2022-2040
Road History	Volumes (Mtonnes)	8.5	11.7	16.0	19.0	+120 %
	Trucks per day	2 200	3 000	4 100	4 900	
Road Low	Volumes (Mtonnes)	8.5	9.6	11.9	12.6	+ 49 %
	Trucks per day	2 200	2 500	3 000	3 200	

[32] The number of trucks is calculated by using the average load for trucks of about 15,3 tonnes and 255 operating days per year (Intraplan and BVU 2014).

Both Road History and Road Low lead to a much larger increase of volumes than even the most favourable rail freight scenarios.

Both Road History and Road Low lead to a much larger increase of volumes than even the most favourable rail freight scenarios.

In chapter 2, different market trends were discussed. Some of them were more favourable for rail transport until 2030, when road transport is expected to have reduced some of the competitive advantage of freight trains in the form of energy efficiency and relatively low climate impact. The following aspects favour rail freight or restrict road transport:

- Energy and fuel prices are expected to increase. This will favour rail, which is more energy efficient.
- Increased focus on environmental sustainability should favour benefit rail freight, thanks to superior energy efficiency. When the needed electricity is produced without greenhouse gas emissions, climate performance is enhanced even more.
- Limited access to truckdrivers. Because of new EU regulations, the access to truck drivers is expected to decrease, which could restrict capacity and increase wages.
- Introduction of road tolls for trucks in Denmark from 2025.

There are, however, factors that favour road transport or disfavour railway transport:

- Capacity constraints. This is a challenge for road as well, but it is more troublesome for rail freight transport. The situation is most serious in Germany, where the government has launched a “first aid for the railways” (BMVDb 2022). In Denmark, the decided infrastructure plan should take care of most bottlenecks during the coming ten to twelve years. In Sweden and Norway, no current plans seem to address the major capacity constraints.
- Limited access to rail infrastructure, as more and more industrial side tracks are shut down. Also, there are many examples of companies moving from locations with access to side tracks to new locations along the motorway system. Both trends mean that access to rail is only feasible via a pre-haulage to a terminal.
- Too few railway terminals and limited competition within and between terminals, particularly in Denmark, limit the use of intermodal road/rail freight transport.
- Rail service constraints in the form of scheduled services with limited capacity between dedicated origins and destinations.
- Technical restrictions of train lengths, particularly in Sweden and Norway, restrictions on maximum speed and requirement of locomotives with multiple signalling systems all add to higher costs for capital and operations. Cross-border transport by rail is also much more demanding compared to road

transport regarding legislation and rules, adding costs for administration (Rail Freight Forward Coalition 2018).

- Access to train drivers. This is a serious challenge in Sweden as well as in Germany (Järnvägar.nu 2023a).

Although decoupling between economic growth and freight transport is considered unlikely, it should be noted that Swedish transport authorities Trafikverket (2020) and Trafikanalys (2022a) have highlighted the fact that the national forecast for freight volumes does not reflect the development of the last years. In fact, Swedish foreign trade has been stable during the last decade measured in weight (Figure 28), though the increase in value has been about 40 % (Trafikanalys 2022a p.14). This, in combination with the weak competitiveness of rail freight during the last decades, give reason to be cautious regarding (too) optimistic future freight volume growth rates.

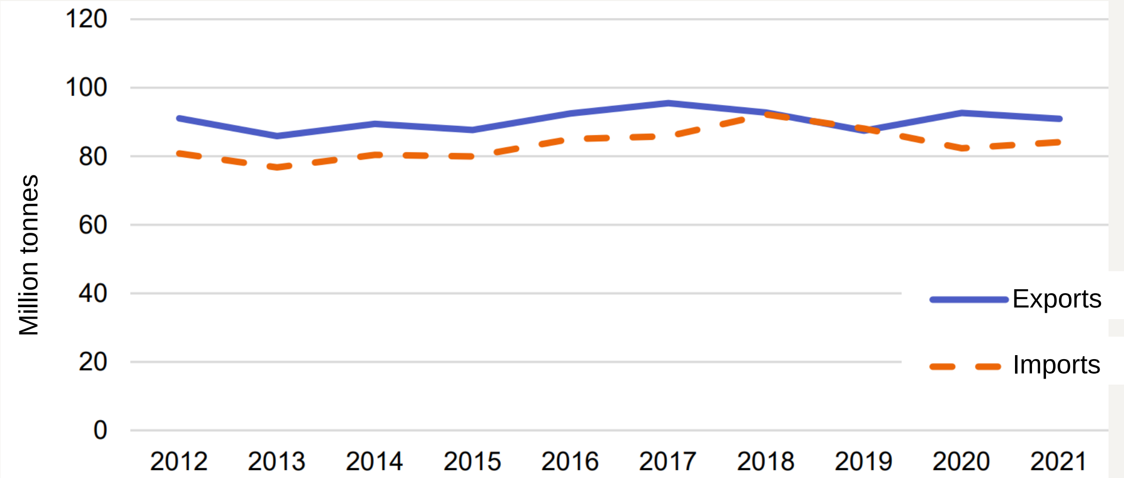


Figure 28. Swedish foreign trade in volumes. Source: Trafikanalys 2022a Figure 2.1.

A rather modest growth for rail freight volumes is supported by for instance the latest German forecast where rail freight volumes are expected to grow by 0.4 % per year until 2051 (Intraplan and TTS Trimode 2023 p.49) and the annual growth rate on the Öresund Fixed Link between 2010 and 2019, which was 1.0 % (Ramboll and MOE Tetraplan 2020).[33]

It should be noted that the average freight train carries 19 % more cargo in 2020 than in 2010 (Trafikstyrelsen 2023 p.15). This means that the expected growth in the positive scenarios above could be managed by using longer/heavier trains, should that development continue.

[33] The number of freight trains on the Öresund Fixed Link has dropped since 2019 (Öresundsbrokonsortiet/Trafikverket 2022).

Although scenario Weak Competitiveness is not deemed likely, it cannot be ruled out, and serves as a reminder that unless the attractiveness of rail freight is improved, a negative development path may be the result.

In sum, a development somewhere between scenarios History High and Average of National Forecasts and History Low seems plausible for rail freight transport. The major obstacles to a more favourable rail freight development are capacity constraints in the rail network, especially in Germany, in combination with the demand structure for logistics services where rail freight is facing challenges. Although scenario Weak Competitiveness is not deemed likely, it cannot be ruled out, and serves as a reminder that unless the attractiveness of rail freight is improved, a negative development path may be the result.

It is very clear that neither History High nor Average of National Forecasts are even close to reaching EU targets. As shown above, neither is the EU on track to reach them. The Average of National Forecasts, considering known political decisions, is comparable to History High.

As shown in Table 17, the forecast that was part of the Swedish-Danish study of a fixed link between Helsingborg and Elsinore indicated an annual growth rate for the Öresund Fixed Link of 1.68 % per year. This would increase transport volumes by about 40 % until 2040. During 2017-2021, an average of 32 freight trains per day have crossed the Öresund Fixed Link. Most freight trains across the FBFL will cross the Öresund Fixed Link. There will also be additional freight trains to/from Denmark and Sweden/Norway on the Öresund Fixed Link. This might indicate a 40 %-increase in freight trains on the Öresund Fixed Link for scenarios History High and Average of National Forecasts.[34]

The problem, however, is not growth rates, but the fact that the railway does not take a larger share of existing transport volumes. How to increase railway competitiveness and bridge the gap between the four scenarios and EU targets will be discussed in chapter 5.

Regarding road freight, it seems likely that the actual development is somewhere in between the two scenarios. By 2030-2040, depending on the growth rate, the number of trucks could lead to severe congestion problems, especially around the larger metropolitan regions. Growth could also be obstructed by lack of truck drivers. The scenarios do not take into consideration the possibility of longer/heavier trucks but assume that the average weight is per truck is constant.

Infraplan and BVU (2014 p.183) states that a remaining, hourly ferry service between Rödby and Puttgarden would reduce the road freight volumes on the FBFL with about 15 %.

[34] There have been some public statements about how future rail volumes across the Öresund Fixed Link are expected to increase with about 200 % (see for instance Järnvägar.nu 2023b). This dramatic claim is based on the assumption that EU targets from 2011 will be reached (AFRY 2021 p.14).

5. Improving rail competitiveness through the Fehmarn Belt Fixed Link and other measures

This chapter starts with identifying the most important quality factors for transport customers/shippers and transport companies when choosing transport mode. Then, the volumes of road transport between Sweden and Norway and Continental Europe are presented. After that, for each quality factor the effect of the FBFL is analysed together with supplementary measures that could improve rail competitiveness.

5.1 The demand for transport and logistics solutions

In many ways, the fixed link across the Fehmarn Belt is a spectacular infrastructure project. Reducing the route for railway transport through Denmark by 160 km is a welcome improvement. Also, the fixed link improves redundancy through Denmark and could have more, important effects. Still, to evaluate the benefit, the effects must be put into perspective relative to the demand for transport services.

In many ways, the fixed link across the Fehmarn Belt is a spectacular infrastructure project.

What is important for shippers is also important for transport companies. If costs are reduced, that benefit is shared between the contracting parties depending on their relative bargaining strength. However, there are also differences resulting in various trade-offs. A rail freight company will typically try to increase efficiency and profitability by longer trains, distributing the fixed costs between more wagons. The shippers might prefer higher frequency and hence shorter trains.

The most important factors to focus on when developing rail transport are (based on Islam et al 2016):

- Reliability of service: This aspect is crucial for many industries and often more important than transport time itself. With just-in-time logistics to reduce inventory costs, and complex supply chains involving multiple links, reliability has gained importance during the last decades. Trafikverket (2012) showed that reliability was the most important criteria for both shippers and transport companies when choosing transport mode. As one freight train equals 40-50 lorries, the consequence of a disturbance is more serious, either by more shippers being affected, or by fewer shippers being more affected. As a result, rail transport should perform better than road transport when it comes to delivery reliability.[35] Today, many shippers actively divide their deliveries on more than one supply chain to reduce the risk of having to stop production. Throughout the pandemic, Russia's invasion of Ukraine, energy and raw material challenges have increased the interest in larger safety stocks in warehouses across the entire supply chain. Nevertheless, the pressure to reduce costs is still strong and there is a trade-off between sufficient safety stock and inventory cost, not least when interest rates increase. Alas, the need for high reliability remains.

- Transport time: as argued earlier, rail can compete when the customer's requested transport time from door-to-door is more than one day.
- Transport costs: This aspect is associated with transport time. Railway operational costs can be competitive compared with road transport when large volumes are combined with relatively long-distance transport and by efficient use of the rolling stock and locomotives.
- Flexible logistics: Service availability at both origin and destination is very important as well as access to attractive time slots in the railway network. Restrictions in the time schedule due to lack of capacity might reduce the efficiency of transport chains through waiting time. Though rail is not able to compete with road transport in terms of flexibility; the higher the frequency of service, the more the disadvantage of rail is compensated.
- Environmental performance: in a survey from as late as 2012 among shippers and transport companies, environmental performance was not even among the eight most important factors when considering transport mode (Trafikverket 2012). This has changed and especially climate mitigation is of strategic importance for many companies and industries. When reducing the climate footprint of industrial production, it is also logical to strive for "green transport". Results from a transport purchasing panel organized by Chalmers University of Technology, University of Gothenburg and IVL Swedish Environmental Institute (2023) show a development towards demanding better environmental performance, albeit slowly. It remains to be seen however, whether this will increase willingness to pay "extra" for environmentally friendly railway transport. So far, the experience is that environmental measures that go together with cost reduction is attractive for shippers. Although environmental performance is important for railway competitiveness, it will not be covered in a specific chapter below, but rather be commented on throughout the report.
- Safety and security: In general, rail freight transport has an advantage over road transport when it comes to safety (smaller risk of shifting in wagons) and security (smaller risk for theft). This is especially important for the transport of high-value goods. As this factor is not specific to the STRING corridor, it will not be further discussed here.

[35] The risk of delayed transports is the likelihood for a delay times the consequence.

The factors above are closely related and impact each other (Figure 29). This will be described in the following chapters, although they cover one factor a time.

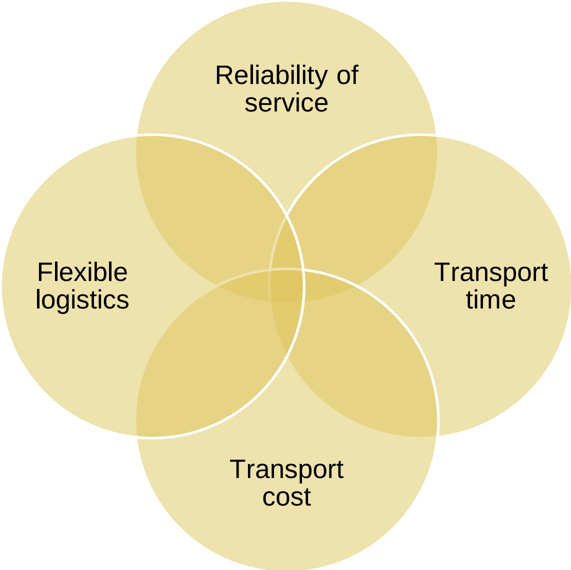


Figure 29. Interdependent factors need to be improved to promote rail competitiveness.

5.2 Road transport

Data from the Swedish authority Transport analysis (Trafikanalys 2023) show about 12-13 million tonnes being transported by road between Sweden and its most important trading partners in Central Europe, see Table 26. Basically, all volumes are transported longer than 300 km. About 50 % of the volumes are goods where the railway is often competitive.

Table 26. Road transport volumes between Sweden and Central Europe. Note that the table includes Denmark. Source: Trafikanalys 2023.

	Exports	Imports	Total
DE	2 438	2 264	4 702
PL	2 022	2 344	4 366
DK	1 907	2 435	4 342
NL	728	783	1 511
CZ	244	298	542
IT	203	293	496
FR	195	179	374
ES	92	259	351
AT	171	129	300
BE	104	174	278
Sum	8 104	9 158	17 262

Figure 29 illustrates total volumes to/from Sweden and the rail market share.

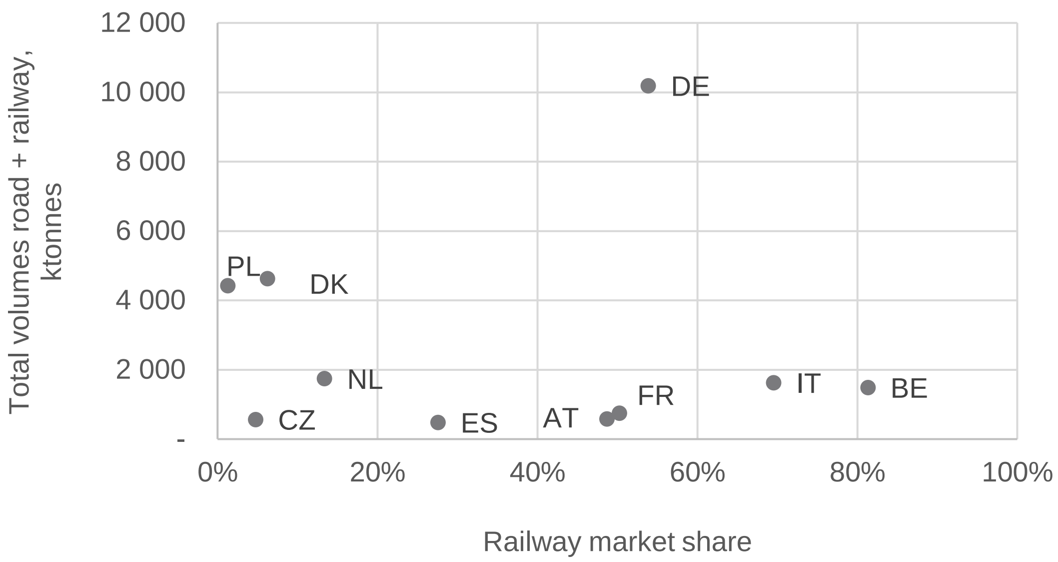


Figure 29. Total volumes being transported and rail market share. Source: Trafikanalys 2023; Sweco.

Note that single flows affect the rail market share considerably for the relations with comparatively small flows. The flows between Sweden and the Netherlands and Belgium are of the same magnitude but are on opposite ends of the scale of rail market share (some 15 % and 80 %, respectively). This is likely an effect of the trainload systems connecting the Swedish and Belgian parts of the manufacturing systems of Volvo Cars and Volvo AB.

Developing rail transport in relations where the rail freight market share is high or total volumes are large or, preferably, both. This is illustrated in Figure 30. Also, when the transport time for the main haul is reduced, rail services can be extended and the catchment area enlarged, with the same requirements for delivery services.

		Railway market share	
		Low	**High**
Total volumes road + railway	**Large**	• Poland • (Denmark) • Netherlands	• Germany
	Medium		• Belgium • Italy
	Small	• Spain • Czech Rep.	• France • Austria

Figure 30. Matrix mapping the estimated potential for rail market expansion.

The matrix in Figure 30 suggests where there is a large potential for railway market expansion. One interesting market is Poland, with large volumes of road freight but almost no railway transport to or from Sweden. According to rail freight operators, relatively high rail access fees and the transit through Germany are limiting the potential, although there are promising concepts to be developed (Sweco 2023b). The Polish railway is suffering from many years of unsystematic maintenance and currently, about 60 % of the network is deemed to be in “good technical condition”. However, Poland is investing heavily to improve the network. One interesting feature though, is that the Polish railway has drastically lost market share from 42 % in the year 2000 to only 10 % in 2020, while road transport has increased more than five times (Pieriegud 2021 pp.43-50).

Norway adds another 3.5 million tonnes to the market including 0.7 million tonnes to/from Denmark (Table 27). One important market driver should be the ambitious export strategy “All of Norway exports”, stating that Norwegian exports, excluding oil and gas, should increase by 50 % until 2030 (Transportetatene 2023b).

Table 27. Norwegian freight volumes with trucks. Source: Statistisk sentralbyrå Table 08811.

(tonnes)	Railway	Road	Railway market share vs road
Poland	31 228	954 796	3%
Germany	52 039	922 034	5%
Denmark	3 106	774 723	0%
Netherlands	6 066	407 407	1%
Italy	83 433	345 215	19%
Spain	3 312	329 664	1%
France	11 037	323 071	3%
Belgium	2 129	194 371	1%
Total	192 350	4 251 281	4%

To conclude, there are large volumes of road transport, some of which could possibly be transferred to rail, if rail freight transport meets the necessary requirements.

5.3 Reliability of service

The tunnel under the Fehmarn Belt improves reliability at both the strategic level and the more operative, technical level. At the strategic level, there will be two railway lines through and to/from Denmark. At the operative level, the fixed link, and the connecting, new and upgraded railway lines will reduce disturbances due to infrastructure problems. The rail corridor between eastern and western Denmark has some problems when it comes to punctuality, as is shown in Figure 31.[36] Also, the railway via the Danish/German border has low punctuality. However, in Figure 31, punctuality is defined as a train not being delayed more than three minutes.

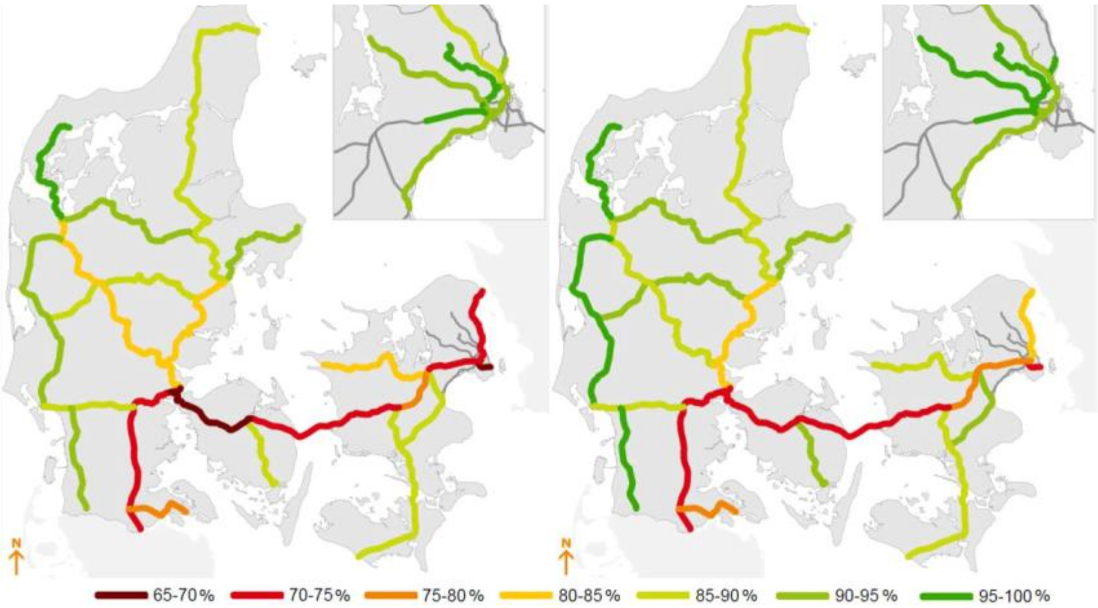


Figure 31. The railway between eastern and western Denmark has some punctuality problems. A train is considered on time if it is delayed no more than three minutes. Source: Trafik, Bolig- og Byggestyrelsen 2017 p.65.

The Swedish Transport Administration (2021 p.36) states that the FBFL removing the dependency on the single railway through Denmark will have a large impact on supply chain options concepts:

> *”The single railway corridor through Denmark and the resulting uncertainty is one reason for operators choosing the nodes Trelleborg and Rostock. When that barrier is removed through the opening of the FBFL in 2029, many operators consider totally new supply chain options.”*

Three things should be noted when it comes to the effect of the FBFL on service availability:

First, the single railway through Denmark will most likely be occupied by other traffic. As many freight trains move to the fixed link, there is a contained demand for, and political will to increase, local and regional passenger traffic. Hence, it might not be

[36] In Denmark as a whole, about one third of delays are due to infrastructure problems. Source: Sweco estimate based on Statsrevisorerna Rigsrevisionen 2017 p.10 and Banedanmark 2023.

that easy just to shift the route in case of a serious disturbance on the eastern, new route.

Second, there is a great uncertainty when it comes to redundancy across the Öresund for rail transport. For rail freight between Sweden/Norway and Germany today, the ferries between Trelleborg and Rostock and the fixed link together offer redundancy. The future of the railway ferries is gloomy. Since the late 1990s, the number of wagons has decreased from 200 000 per year to 20 000 (Trafikverket 2021c p.3). That was before Green Cargo transferred 7 000 wagons from the ferries to the fixed link to reduce both lead times and costs (Dagens Logistik 2021). The redundancy offered by the ferries is important for operators and shippers, but capacity utilization is very low. The shipping company Stena Line states that transport with rail ferries must increase considerably to ensure a reasonable profitability if they should invest in railway capability for the next generation of ships (Trafikverket 2021c p.3).

Third, even though reliability is improved through Denmark, much remains to be done within the STRING corridor and in adjacent countries and regions. In 2021, punctuality for DB Cargo was 73 %[37], a figure that during the first part of 2022 had fallen to 65 %. About 80 % of the disturbances are caused by the infrastructure (BMDV 2022a). In Sweden, punctuality for freight trains was 77.9 % in 2019[38] (Nilsson and Öberg 2020 p.2) and in Norway it was 76 % in 2022[39] (Bane Nor 2023). In the Scan-Med corridor, from January 2018 to June 2019, close to 25 % of all freight trains were more than 6 hours delayed (Cox 2022 figures 10 and 11). Considering this, one clear possibility is that the time gained from the FBFL (see chapter 5.4) will probably often be utilized as a safety margin.

The pandemic can be seen as a “field experiment”, illustrating the effects of removing infrastructure capacity constraints, although this was achieved by having fewer passenger trains and passengers rather than by removing physical bottlenecks. In Germany, punctuality for DB Cargo was close to 85 % in 2020 (BMDV 2022a). In Norway, punctuality temporarily rose to over 82 % in 2020 (Bane Nor 2022). In the ScanMed-corridor, the share of freight trains delayed more than 6 hours was slightly more than 10 % in 2020, considerably better than the figure presented above (Cox 2022 figures 10 and 11).

5.4 Transport time

With an average speed of 70 km/h, a 160 km shorter route equals approximately 2.5 hours of reduced transport time. This has clear advantages for the operators:

- Costs are reduced, both operating costs (personnel, energy) and capital costs for rolling stock and locomotives.

[37] Defined as a freight train being no more than 16 minutes delayed.

[38] Defined as a freight train being no more than 5 minutes delayed.

[39] Defined as a freight train being no more than 6 minutes delayed.

- Goods need to be delivered from A to B within “X hours”. If the transport time for the railway is reduced, the first and/or last mile could be extended, thus increasing the catchment area for a transport chain with intermodal transport. Another possibility is to use the reduced transport time as a buffer time for disruptions and disturbances, thus increasing reliability.
- Shorter turn-around time could lead to more transport cycles per time unit, hence increasing the utilization of the fleet.

Using a case study with a railway transport between Berlin and Stockholm (Eskilstuna) via Denmark, the FBFL reduces transport time door-to-door by 10 %, from 23 hours to 20.5 hours (Sweco based on Atkins and Trafik-, Bygge- og Boligstyrelsen 2020 p.49). Cox (2022 p.33) uses the indicator “commercial delivery time” that measures an intermodal rail service between a Baltic Sea Port (on the Southern coast) and a freight hub in Italy. The journey time was around 29-30 hours during the first six months of 2021.

Still, there are cases where the time reduction leads to a more dramatic threshold effect. Sweco (2023c) studies freight trains between Duisburg and Katrineholm. There is one daily connection in each direction. The train is 700 meters, with 21 wagons and 42 units (such as semi-trailers and containers). Transport time is less than 24 hours per direction and terminal time is 3.5 hours. Today, four train sets are needed to run the operation. Two sets are rolling and 1 + 1 are loading/unloading in each terminal. Hence, two locomotives and 84 wagons are needed. The annual leasing fee for each wagon is 22 000 €, in total 1 850 000 €. With the FBFL and slightly faster terminal handling, the transport time is reduced to such an extent that a train is loaded in Duisburg, hauled to Katrineholm, unloaded, and loaded in under 24 hours. Hence, the need for wagons is reduced by half and the rail operator will save more than 900 000 € in leasing fees annually. Although the example might be a bit optimistic with small marginals for delays, the principle is clearly relevant.

One measure to increase railway competitiveness is through faster trains. The infrastructure standard in the EU green freight corridors is 100 km/h. Boehm et al (2021) simulates the effects of 160 km/h speed and gets a railway market share of 42 % compared to a lorry with semi-trailer for low-density, high value cargo a market segment where railway typically have difficulties to compete. However, most studies focus on reaching 120 km/h (see for example KombiConsult and Ramboll 2020; Trafikverket 2021 and Islam et al 2016).

Trafikverket (2021a p.46) shows that with the maximum allowed speed of 120 or 140 km/h, a daily shuttle system increases its radius of action from 550 km to 700 km and 900 km, respectively. That is the radius of action where a trainset can be used for one return transport per day. If a train is to leave at 6 PM and arrive at 4 AM, the effective radius of action is increased from 700 km to 900 km and 1 150 km, respectively. In a simulation of the effects on railway competitiveness, 120 km/h could increase rail transport work by up to 2 billion tkms per year, transferring equal parts from road and sea (Trafikverket 2021a pp.46-47; Trafikverket 2022 p.6).

A very positive effect of faster freight trains is that it increases capacity in the railway network. When trains at different speeds ply the same railway route, the slower trains will take up a large part of the capacity. With more fast trains, the trains are on the current route for a shorter time, thus freeing up capacity for more trains. Most locomotives and rolling stock are designed for higher velocities (Trafikverket 2021a p.46).

Capacity constraints lead to waiting times, not only on railway routes, but also for handling at intermodal terminals.

However, current average speeds indicate that more needs to be done to increase railway utilization. Cox (2022 p.33) shows that the average speed from a seaport on the south coast of the Baltic Sea to a terminal in Italy is only slightly higher than 40 km/h in 2021. KombiConsult and Ramboll (2021 p.16) argue that freight trains have a low priority when scheduling and often must wait for faster passenger trains passing by. Capacity constraints lead to waiting times, not only on railway routes, but also for handling at intermodal terminals. The latter is worsened by delays causing the freight trains to miss their dedicated time window at the terminal. Also, border procedures tend to be time-consuming, although they are probably less so in the STRING corridor than in other border relations. Transhipment is also time-consuming because of waiting times due to various schedules, for instance railway/ferry. The FBFL directly addresses this issue, enabling more direct shuttle trains without any need for coordination with ferries.

5.5 Transport costs

The FBFL will have a positive impact on transport costs. Both the 160 km shorter tour and 2.5 hours reduced transport time decrease operating costs (personnel, energy, rail access fees) and capital costs (including tear and wear). Increased reliability might reduce the need for safety stocks or reserve capacity, for logistics service providers and manufacturers of goods. In the case study from Berlin to Stockholm (Eskilstuna) via railway through Denmark, the FBFL reduces the transport costs by about 10 % (Sweco based on Atkins and Trafik-, Bygge- og Boligstyrelsen 2020 p.49). In some cases, the time savings might lead to large threshold effects as shown in chapter 5.3.

The costs for an intermodal transport using rail freight have been illustrated by Atkins and Trafik-, Bygge-, og Boligstyrelsen (2020), see Figure 32. The share related to first/last mile transport is much dependent on the length of the main haul. The longer the railway transport, the less impact these costs have on total transport costs. In general, a share of 30-35 % for transport under 300-400 km is common (Atkins and Trafik. Bygge- og Boligstyrelsen 2020 p.3). The same conjunction is valid for the costs of terminal handling. For Danish railway transport, costs for terminal handling account for about 9-15 % of total costs (Trafik- og Byggestyrelsen 2016). Many studies show that low-priced and efficient intermodal terminals play an important role for railway competitiveness (Transportministeriet 2021a p.20).

Load unit	**First mile**	**Intermodal terminal**	**Rail transport**	**Intermodal terminal**	**Last mile**
Rental of the load unit used in the transport: 40/45" Container Semi-trailer Crane able Semi-trailer Swap body 7,45	From shipper to intermodal terminal	The truck delivers the intermodal loading unit to the intermodal terminal, where it is placed in waiting position until the train is ready to be loaded. Later the unit is loaded onto the intermodal rail wagon.	The train wagons are collected in the terminal and often taken across borders towards the destination terminal. Along the route staff changes, shunting and change of locomotive can take place.	The train arrives in the intermodal terminal and the units are lifted off the wagons – either directly onto a wating truck or put in a storage until the truck collects the unit	The last mile transport takes the unit from the intermodal terminal to the destination, i.e. an industry, trading company or warehouse.
Cost occurring: Daily rental	Cost occurring: Vehicle leasing Driver/staff Insurance Fuel Infrastructure fee Administration	Cost occurring: Lift load unit Storage short term Access fee Administration	Cost occurring: Vehicle leasing	Cost occurring: Lift load unit Storage short term Access fee Administration	Cost occurring: Vehicle leasing Driver/Staff Insurance Fuel Infrastructure fee Administration

Figure 32. The cost structure of an intermodal transport. Source: Atkins and Trafik-, Bygge-, og Boligstyrelsen 2020 p.24.

A specific issue concerns the costs of terminal handling in Denmark. Trafik- og Byggestyrelsen (2016) showed that the costs for handling a unit are considerably higher in Danish terminals compared to terminals in Sweden, Germany, and Italy (Figure 33). Trucks from the Rödby-Puttgarden and Gedser-Rostock routes and also Elsinore-Helsingborg could move to the railway if the Höje Taastrup terminal is strengthened as a node.

The costs for handling a unit are considerably higher in Danish terminals compared to terminals in Sweden, Germany, and Italy

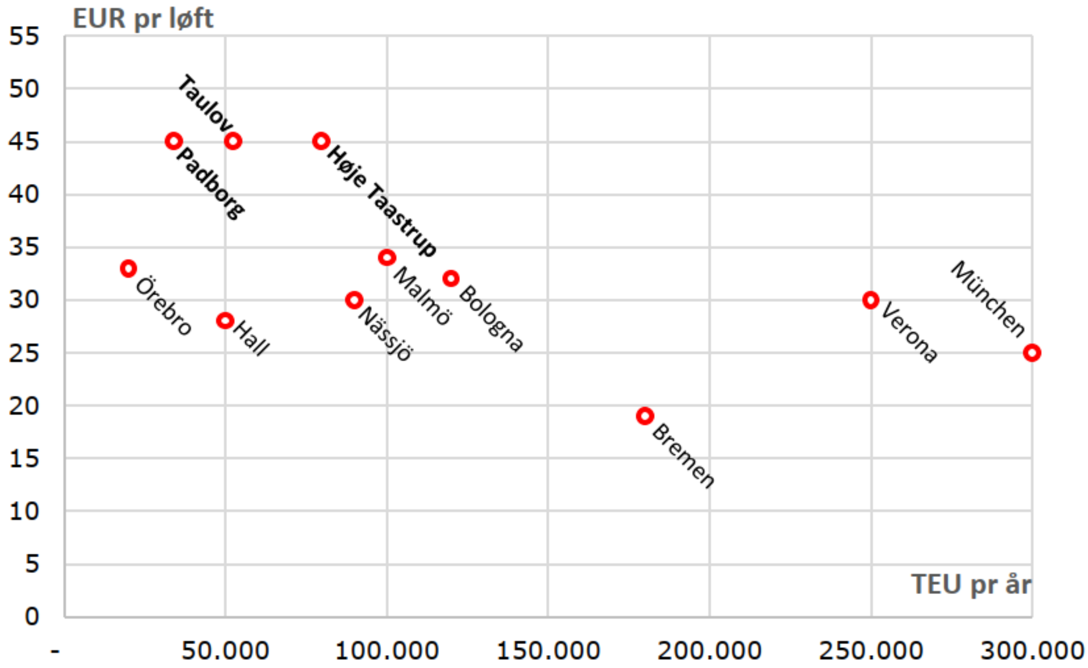


Figure 33. Costs for handling a unit at various intermodal terminals. Source: Trafik- og Byggestyrelsen 2016 Figure 2.

The length and weight of the train play a very important role in terms of transport costs, as the share of fixed costs is reduced. Typically, it is the last few wagons on a freight train that make the transport profitable. With every added wagon, profitability increases. This development has already been very apparent on the fixed link across Öresund (Figure 34).

The length and weight of the train play a very important role in terms of transport costs … With every added wagon, profitability increases.

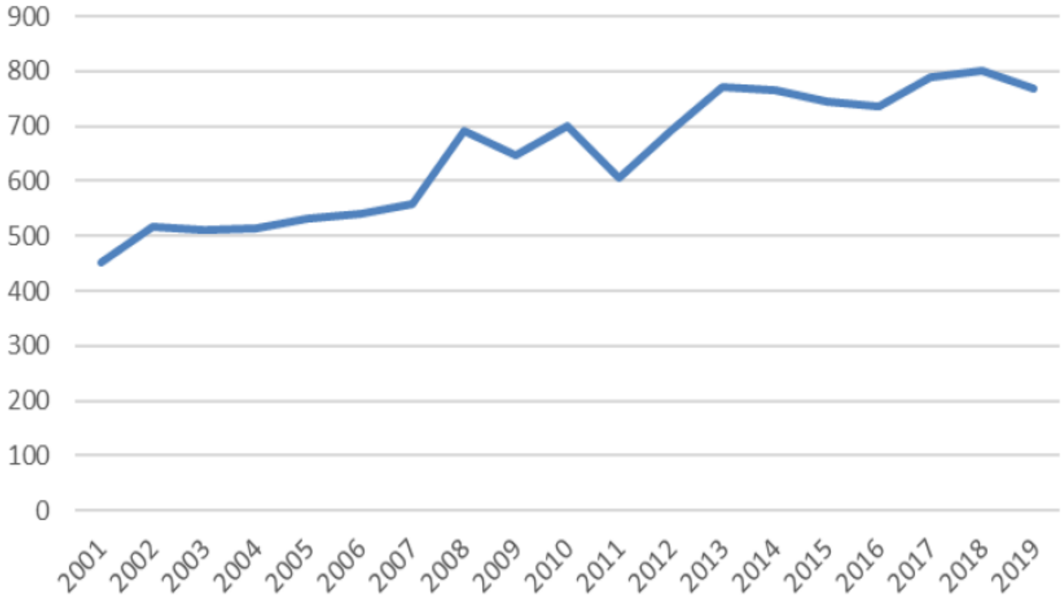


Figure 34. The diagram shows how average volumes per freight train have increased over time. Source: Øresundsbrokonsortiet/Trafikverket in Ramboll and MOE Tetraplan 2020 p.23.

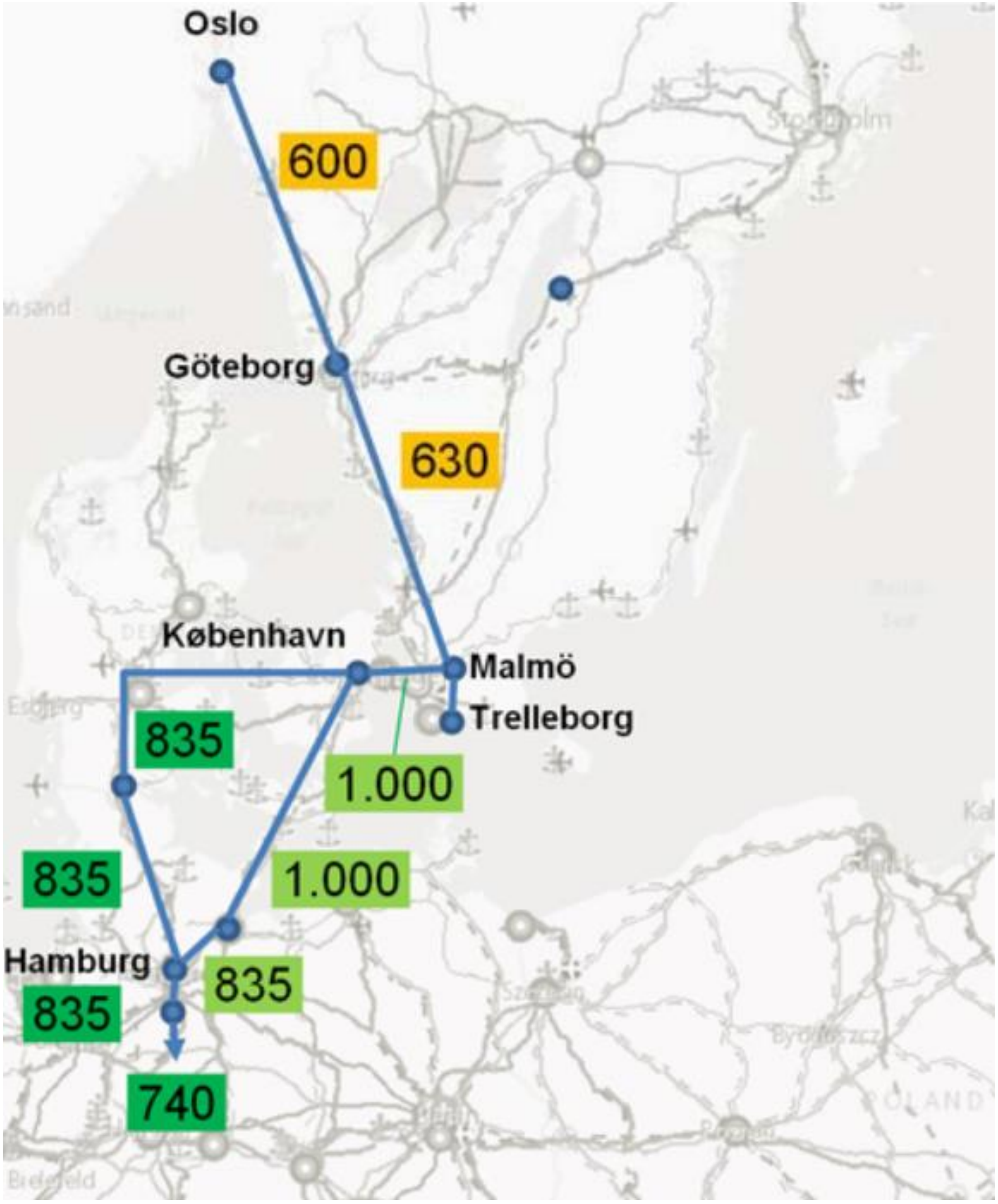


Figure 35. Overview of possible train lengths. Source: KombiConsult and Ramboll 2021 p.18.

KombiConsult and Ramboll (2021 p.18) show that Sweden and Norway have restrictions that prevent 740-metre-long trains. South of Sweden, the STRING corridor allows for 835-metre-long trains.[40] A 740 metres long freight train can carry about 17 % more load than a 630-metre-long train. An 835-metre-long train can carry one-third more freight volumes than a 630-metre-train.

[40] With supplementary railway improvements between Lübeck and Hamburg, it would be possible to operate freight trains 1 000 metres long between Hamburg and Malmö. The marshalling yard in Malmö does not have the sufficient capacity, however.

Another important effect is that the capacity of the railway is improved when each train carries more weight. In a theoretical scenario, if all trains are 630 metres long and are replaced by 835-metre-long trains, the number of trains needed to meet demand is reduced by 25 %.

Also, environmental performance (and associated cost efficiency) is improved with longer trains, as Jernbanedirektoratet (2019a) shows, see Figure 36.

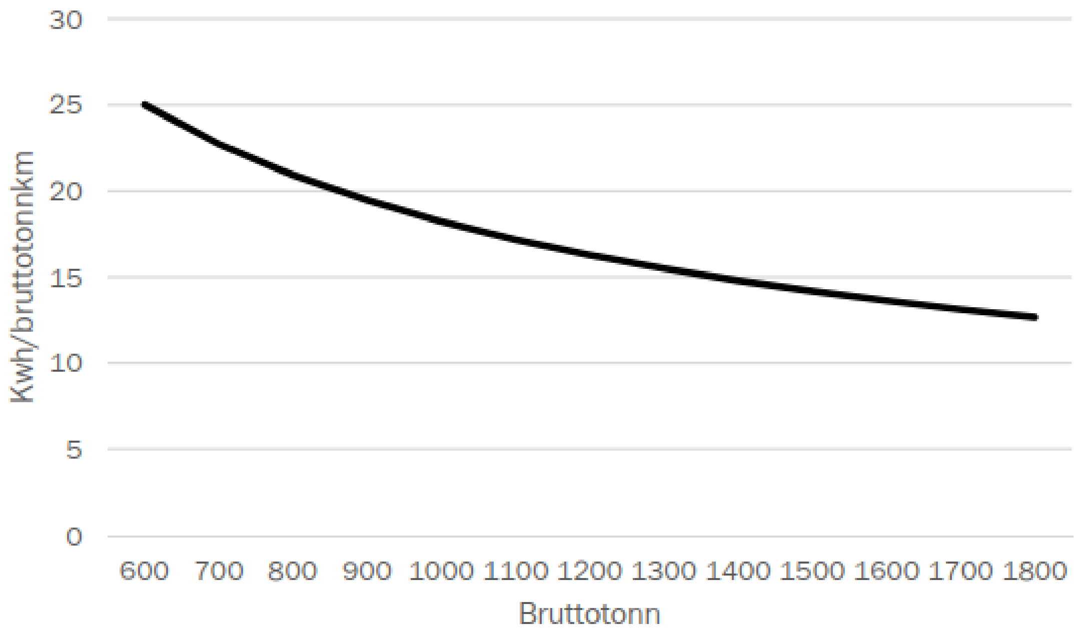


Figure 36. Energy consumption (kWh per gross tonne-kilometre) is reduced with higher train weight (gross tonne). Source: Jernbanedirektoratet 2019a p.27.

Both in Norway and Sweden, the potential gains from allowing longer/heavier trains are large.

Both in Norway and Sweden, the potential gains from allowing longer/heavier trains are large. Jernbanedirektoratet (2019b pp.2-3) includes both longer trains and efficient intermodal terminals as the two bearing pillars of the rail freight strategy. TØI and SITMA AS (2019) demonstrate that longer freight trains[41] would lead to 3.4 million more tonnes being transported by rail in 2030. In comparison, the FBFL only adds 0.1 million tonnes. The baseline is around 11 million tonnes excluding ores (TØI 2022 p.III). Longer trains seem to have a very large potential for increasing rail volumes in Norway. Restrictions on train length are mentioned as one important reason for Green Cargo closing their domestic Norwegian routes in 2022 (Järnväg.nu 2022).

Both Norway and Sweden are working to enable longer trains, most notably by lengthening passing loops. It is unclear, however, when both countries will facilitate

[41] The simulation includes train length for commuter trains 740 metres on the sections in/out of Norway (Oslo-Kongsvinger-Sweden) and Oslo-Kornsjø-Sweden). For combined trains Oslo-Bergen, Oslo-Trondheim and Oslo-Ganddal, the length is set to 640 m, and for Trondheim-Bodø to 600 m.

well-functioning railway transport with longer trains. As can be seen in Figure 37, Sweden is planning to improve capacity for longer trains. But by 2030, capacity constraints will seriously obstruct traffic on large parts of the network, notably around Gothenburg, in Southern Sweden and on the Western and Southern Main Lines.[42]

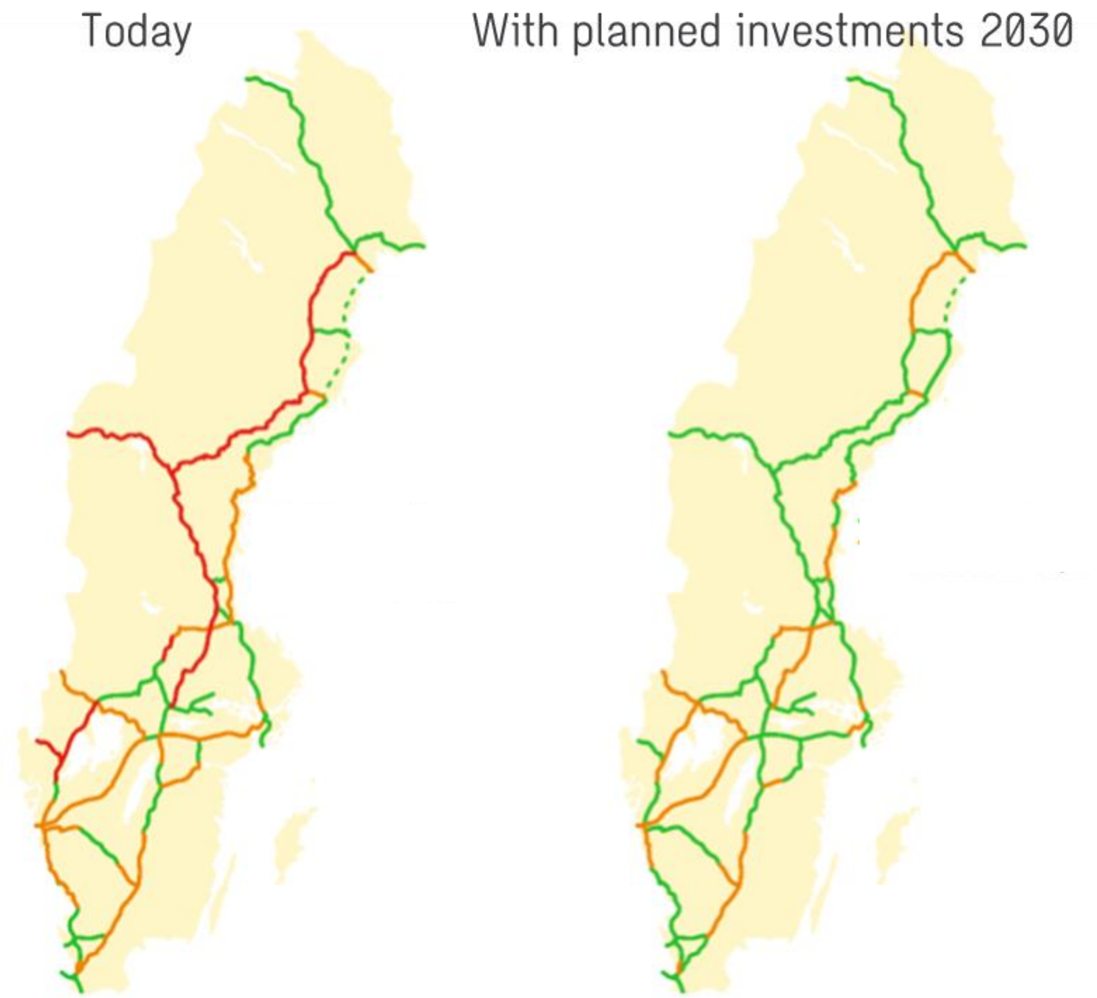


Figure 37. Maximum train lengths on the Swedish rail network. Green colour: 750 m possible. Orange: 750 m possible, but lack of capacity seriously obstructs traffic. Red: 750 m not possible. Source: Trafikverket 2021b p.28.

5.6 Flexible logistics

The FBFL and connecting, new and improved railways will to some extent increase logistics flexibility by allowing for more trains and more time slots. Outside rush hours, there will be three hourly time slots for freight trains through Denmark, two via the FBFL, and one via Great Belt Fixed Link (Trafikstyrelsen 2023 p.15). As argued in chapter 5.3, strategic redundancy offers flexibility in case of disturbances. When catchment areas are widened thanks to reduced transport time on the main haul from

[42] It should be noted that the network in figure 37 is only the main network.

Scandinavia to Central Europe, it is likely that there will be a geographic market area sufficient for more freight trains.

However, the forecast from 2014 (Intraplan and BVU 2014), model simulations in Norway and Sweden and case studies indicate that the expected effect from the fixed link alone is limited. One important reason is the remaining capacity constraints in other parts of the railway system, reducing the benefits of the FBFL. Although there are more time slots through Denmark, the bottlenecks prevent this advantage to be fully utilized. This will be discussed in chapter 6.

Illustration of the portal area at Puttgarden on Fehmarn after construction. Source: Femern A/S

5.7 Conclusions – Improving rail freight competitiveness through FBFL and other measures

The FBFL adds strategic and operative reliability through Denmark. Still, many challenges remain and must be dealt with. Railway transport perform poorly with respect to punctuality in the entire corridor, to a large extent because of capacity constraints and lagging maintenance. It is uncertain whether the railway ferries will remain in operation and if they do not, strategic redundancy between Sweden/Norway and Denmark/Germany is missing despite the FBFL.

The effects of the time gains from the FBFL will span from increased safety margins, adding to the reliability, to reduced costs through potential threshold effects. For many logistics chains the effects are relatively limited, but it seems likely that the potential for direct shuttle trains will increase, adding time gains as coordination needs with other time schedules are reduced. To increase railway competitiveness, many more initiatives are needed. Faster trains would meet long-term logistics trends rewarding shorter transport times. They would play an important role in increasing railway capacity. Faster trains clearly have a large potential to increase the operational area, hence enlarging catchment areas and possibly lead to either or both of the following effects, a) making new freight train routes profitable, b) increasing the profitability of existing railway transport. However, running faster trains on individual stretches might not give any advantage if bottlenecks remain, either in the railway network or in the terminal infrastructure of intermodal transport chains.

The potential for longer and heavier trains appears especially large as they reduce fixed costs per tonne moved, improve energy efficiency, and increase network capacity.

The FBFL will lead to a welcome reduction of transport costs. Although the effects vary depending on the transport chain, case studies indicate a 5-10 % cost reduction. In some cases, the effect could be considerably more thanks to threshold effects, but the cost reduction could also be lower. Transport costs could also be reduced through faster trains, as shown in chapter 5.4. Of specific concern is the comparatively high fees for handling units at the Danish intermodal terminals.

However, the potential for longer and heavier trains appears especially large as they reduce fixed costs per tonne moved, improve energy efficiency, and increase network capacity. Although the STRING corridor in general has comparatively favourable conditions for longer trains, capacity constraints obstruct traffic and are expected to remain until at least 2030.

The Öresund Fixed Link opened in the year 2000 and led to a strong development of all transport across the Öresund. The FBFL does not change the playing field as dramatically. The Öresund Fixed Link made it possible to operate freight trains and trucks between Scandinavia and Continental Europe without any transfer to a ferry. This was a radical improvement. The FBFL will give clear advantages to freight transport on land, but with a more marginal improvement.

6. Railway capacity

This chapter analyses the effect of infrastructure capacity constraints on railway competitiveness. The situation in the four countries in the STRING corridor is described and the chapter ends with a list of high-priority investments.

6.1 The negative impact of capacity constraints

One important result from the analysis so far is that capacity constraints obstruct a modal shift from road to rail. The reason is that bottlenecks, single-tracks, restrictions on train length or weight, speed reductions, steep gradients, lack of terminal capacity and other infrastructure shortcomings have a negative impact on every one of the most important factors when choosing transport mode (Table 28).

Table 28. Capacity constraints severely affect railway competitiveness.

Factor	Impact of bottlenecks and capacity constraints
Reliability of service	Disturbances have more severe effects and are transmitted through the system. The time to restore traffic is long. Timetables need more safety marginals, increasing the difference versus road transport.
Transport time	Trains must wait for each other, and freight trains are most often downgraded in favour of passenger trains. The slowest trains (the freight trains or local passenger trains) define the capacity of the railway. Freight trains are often given low priority relative to passenger trains, adding to longer transport times.
Transport costs	Longer transport times due to capacity constraints lead to lower utilization of rolling stock and locomotives, hence increasing the share of fixed costs and reducing railway competitiveness. When train length or weight is restricted, cost efficiency is reduced.
Availability and flexibility	Lack of available time slots reduces flexibility. Bottlenecks in the railway network define the entire logistics chain, leading to unwanted effects at the origin or destination.
Environmental performance	Longer transport times and frequent stops, leading to more braking and acceleration, might increase energy consumption. When train length or weight is restricted, energy efficiency is reduced.

The need to ensure sufficient capacity is clearly expressed by the Norwegian transport authorities:

> *"The railway is the mode of transport in which capacity constraints in the infrastructure to the greatest extent both limit the possibilities for volume growth and limit the development of transport services that are in line with the needs and expectations of transport buyers." (Norwegian transport authorities 2023a p.4)*

For the STRING corridor, this is particularly problematic. The conditions for railway traffic, the most efficient and environmentally friendly way of transporting large flows of both passengers and goods, are favourable in a densely populated corridor with substantial industry production and many important nodes. However, capacity constraints lead to destructive competition between transport demands that are equally important from the perspective of society.

Railway traffic, the most efficient and environmentally friendly way of transporting large flows of both passengers and goods, are favourable in a densely populated corridor with substantial industry production and many important nodes

In the following sections, capacity constraints in the STRING corridor are illustrated. The situation is analysed more in detail in KombiConsult and Ramboll (2021) and Cox (2022). The latter states that the corridor is living up to EU standards for the freight corridors and the TEN-T network, with the notable exceptions of train length in Norway and Sweden and ERTMS in all countries.

6.2 Germany

The German railway network is facing severe challenges. In 2022, approximately 3 500 km of the network was highly loaded, a figure that is expected to increase to more than 9 000 km in 2030, see Figure 38. The average capacity utilization on those parts of the net is 125 % (BMDV 2022b).

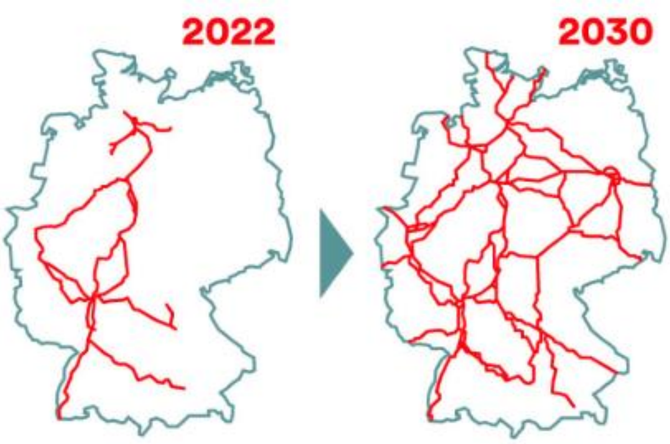


Figure 38. The German railway network described as "highly loaded". Source: Bundesministerium für Digitales und Verkehr 2022b.

The ministry identifies the railway node Hamburg, with the southbound corridor to Hannover, as one of the most utilized corridors in the entire country, see Figure 39.

Figure 39. The map shows the railway corridors with the absolute highest utilization. Source: Bundesministerium für Digitales und Verkehr 2022a p.2.

In Figure 40, projects in the category “urgent need” are shown in red. The connection to the FBFL is one of them.

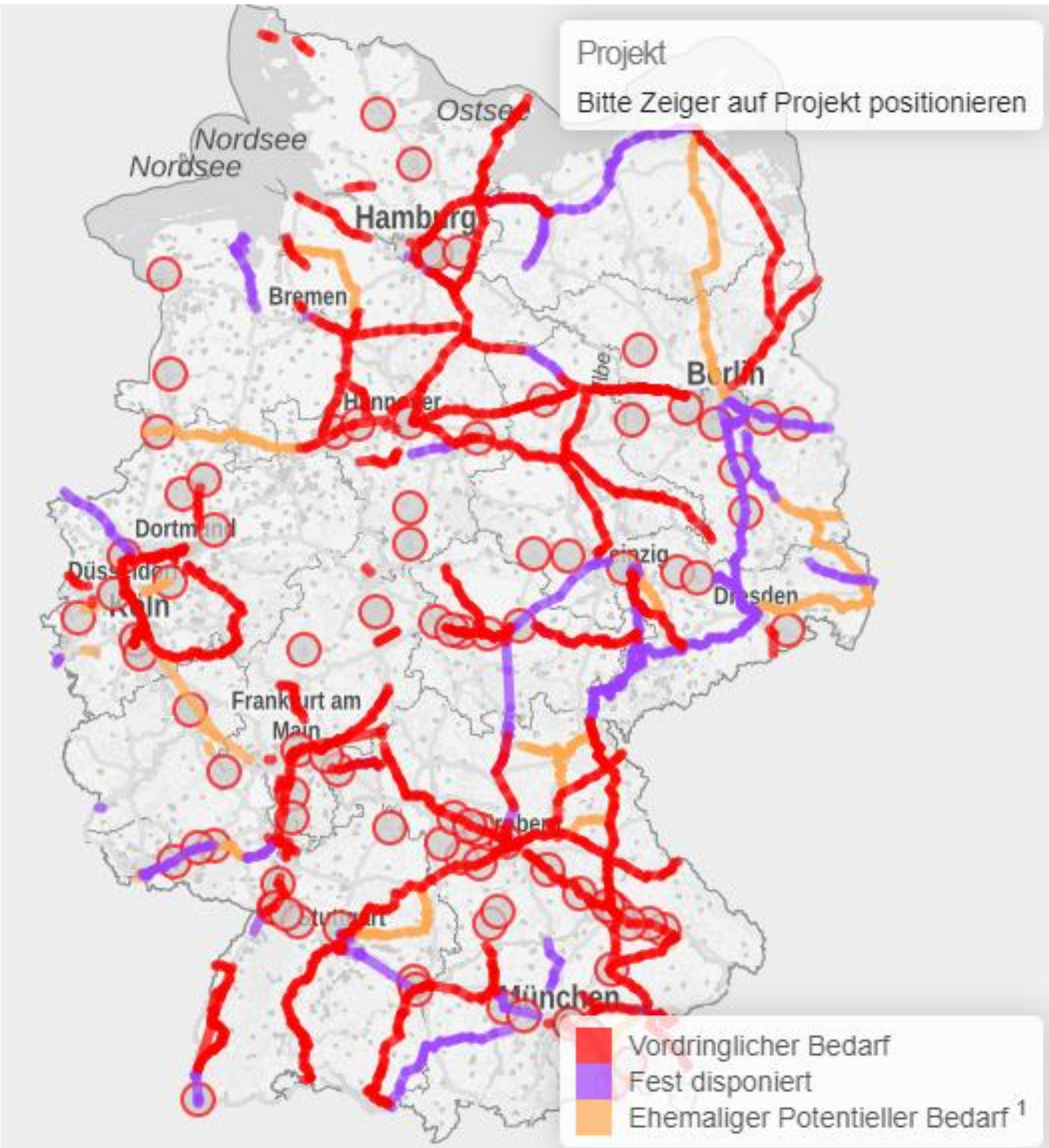


Figure 40. Project information from the Bundesministerium für Digitales und Verkehr. Red means “urgent need”. Source: BMDV 2022e.

In December 2022, the responsible Federal Minister presented 70 specific recommendations from the so-called “acceleration commission for the railways”. The recommendations have been developed by representatives from the entire sector and are to be reviewed and implemented as soon as possible. This package is complementary to larger infrastructure improvements and is increasing the chances of improving the railway system. One focus is small and medium-sized measures that can quickly make an effective contribution to increasing resilience and punctuality in the network. For instance, the commission recommends reducing the scope and duration of approval procedures for small and medium-sized measures (BMDV 2022c).

6.3 Denmark

In Denmark, expected traffic development means a need for more capacity close to the fixed link across Öresund. Also, the expected relief for the railway line between Jutland and Fyn is dependent on an extra, parallel track not yet politically decided, but shown in Figure 41. Transportministeriet (2021 p.8) states that only 41 % of the capacity reserved for freight trains between Padborg on Jutland and the fixed link across the Öresund is utilized, indicating an existing potential.

In the current Danish infrastructure plan (Transportministeriet 2021b p.20), some serious bottlenecks constraining rail transports are described:

- The railway through Ringsted is a significant bottleneck, leading to extended transport times and delays. When the Fehmarn Belt connection opens in 2029, the challenge will be even greater. An expansion of capacity promotes passenger traffic and improves conditions for rail freight transport.
- Copenhagen Central Station is highly utilized and constitutes a bottleneck, effectively obstructing rail transport development. A new southern rail corridor around Copenhagen Central Station would increases capacity and enable more efficient transport in several directions. This requires, among other things, an expansion of Copenhagen Airport Station and passing tracks for freight trains at Kalvebod.

The necessary investments are further described in chapter 0.

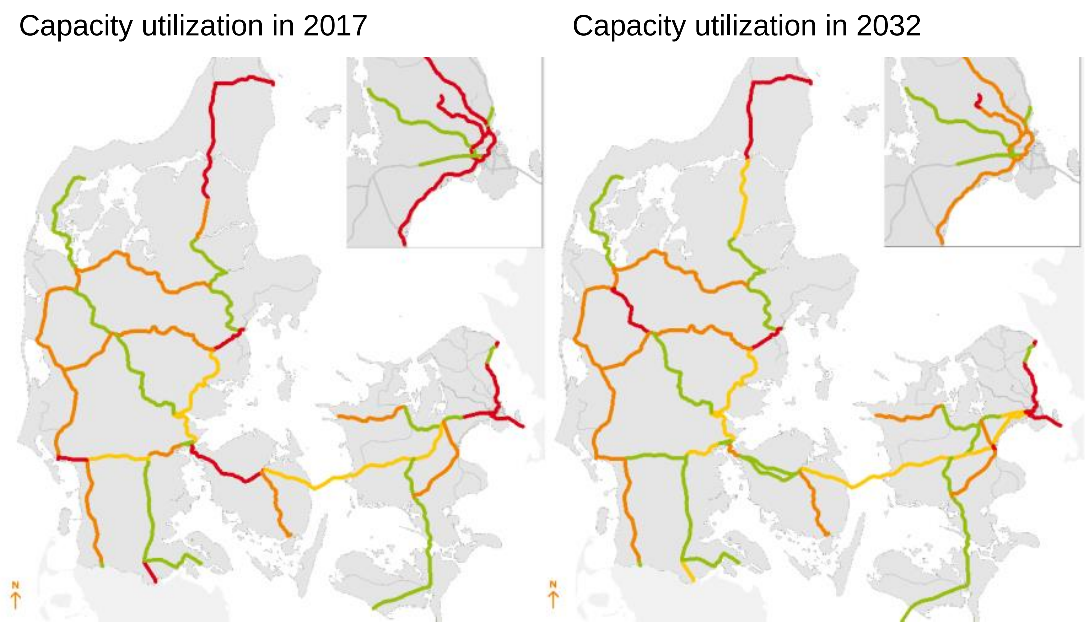


Figure 41. Capacity utilization on the Danish railway network in 2017 and 2032 (forecast). Red means high utilization with need for more capacity. Orange means high utilization but no need for further capacity. Source: Trafik-. Bygge- og Boligstyrelsen 2017 p.67.

6.4 Sweden

Capacity constraints for the Swedish railway network are shown in Figure 42. Although the railway along the West coast is not that problematic, there is a great need for investments in the connecting Western Main Line (Gothenburg-Alingsås) and the Southern Main Line (in Southern Sweden). At the time of writing, there are no investment plans for either distance, and the planning for new high speed main lines that would free capacity for freight on existing lines is halted by the government. This means that Figure 42 is slightly misleading, as it indicates that the capacity constraints on the Southern Main Line are managed by 2030. This will most likely not be the case.

When looking at capacity utilization during the 2 hours with the most traffic, the picture, not surprisingly, worsens.

Figure 42. Rail capacity in Sweden. Red indicates a significant shortage of capacity for freight transport measured over the day (capacity utilization >80% and ≥ 20 freight trains per day). The map on the left is 2019 and the right is with investments according to the national transport plan 2018-2029 with the base forecast for 2040. Source: Trafikverket 2021b p.21.

6.5 Norway

The lack of capacity is highlighted as the most important constraint for rail freight development in Norway, where already today applications for train slots exceed supply on several routes. (Norwegian transport authorities 2023a pp.23-25).

The railway network in the Oslo region has severe capacity challenges, leading to disturbances affecting transport quality. There are restrictions for freight trains on specific links during rush hours (Transportetatene 2023a p.48).

In the railway corridor between Oslo and Gothenburg, there are several non-favourable conditions such as long transport times, steep gradients forcing operators to either reduce train length or use two locomotives. (Transportetatene 2023a p.50). Current rail volumes in the corridor are estimated to be 1.9 million tonnes with a market share of 4 %. Until 2060, volumes are expected to grow by 60 %, equal to a CAGR of 1.2 % (Transportetatene 2023a pp.52-53; Sweco).

In the Norwegian cargo strategy from 2019, efficient terminals and longer trains are vital recommendations for infrastructure development. For the railway between Oslo and Gothenburg (Östfoldbanen), the recommendation is to enable 740-metre-long trains. There are also plans to substantially increase capacity at the Alnabru intermodal terminal outside Oslo to meet demand (Norwegian transport authorities 2023b pp.23-25). The Alnabru terminal handles about half of all containers being transported on the Norwegian railway and the terminal is experiencing capacity problems (Transportetatene 2023a pp.46-47).

The Norwegian transport authorities (2023 p.5) also express a possible need for more nodes, enabling and promoting cooperation between transport modes. Such intermodal nodes might be established in ports in the Oslo fiord or close to Gardermoen Airport/Hauerseter.

6.6 The need for infrastructure investments

Capacity constraints are obstructing a modal shift towards more railway services. The necessary projects to remove bottlenecks and capacity constraints are presented in two categories:

A. Elements already restricting the competitiveness of rail transport

B. Elements that will restrict railway transport competitiveness by 2030

Due to the long infrastructure planning processes, which is a challenge in itself, all infrastructure projects must be worked on as soon as possible. Note that ongoing projects are not included, for instance in Gothenburg, in and around Hamburg, and on the West Coast Line in Sweden.

Due to the long infrastructure planning processes … all infrastructure projects must be worked on as soon as possible.

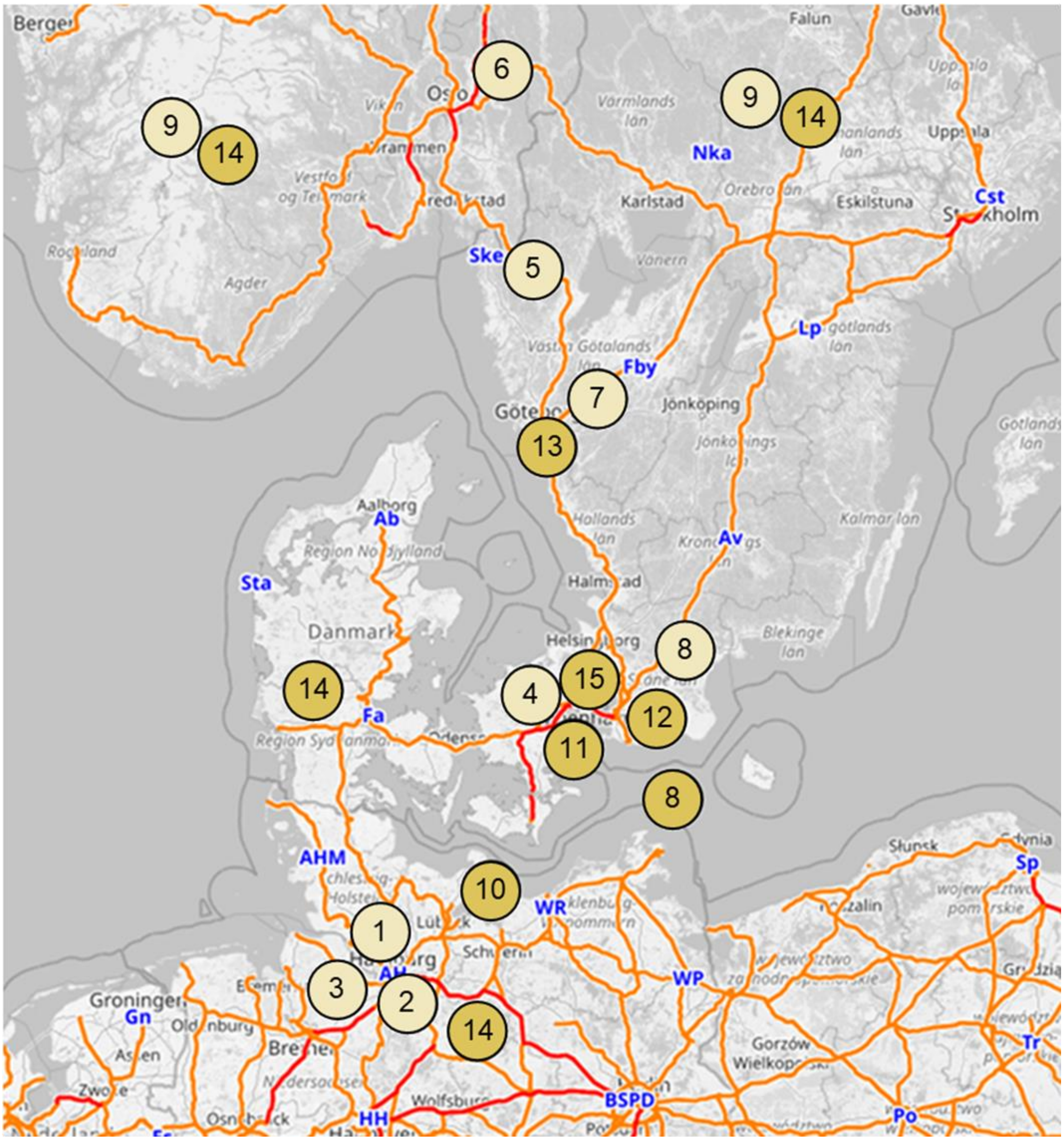
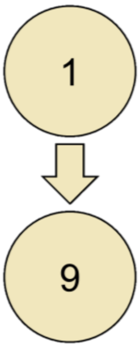


Figure 43. Infrastructure challenges that are already obstructing rail transport or will do so by 2030. Map: Open Rail Map, www.openrailmap.org



Category A

1. Rail node Hamburg. Hamburg is not only a large metropolitan region, but also at the crossroads between three TEN-T corridors; the North Sea-Baltic, the Orient-East Med and the Scandinavian-Mediterranean. The port of Hamburg is the third largest seaport in Europe in volumes (Port of Gothenburg 2023) as well as the third largest container port, hence an important transport hub for global trade. It is also the largest railway port in Europe, adding to its importance for intermodal transport. The German programme to improve local and long-distance passenger traffic and freight traffic, the “Deutschland-Takt“, will further strengthen the Hamburg railway node. The railway between Hamburg Central Station and Hamburg-Harburg is the main connection for traffic to/from Central, Western and Southern Europe and is highly utilized with about 600 trains per day, including 225 freight trains. The bridges over the river Elbe must be renovated, creating an opportunity to increase capacity from four to six tracks (Freie und Hansestadt Hamburg 2023).

2. The railway Hamburg-Hannover. As shown in chapter 6.2, the railway between Hamburg and Hannover is one of the most utilized transport corridors in Germany. There is an urgent need for two more tracks to increase capacity.

3. Hamburg terminal capacity. The Port of Hamburg is one of the largest logistics and industrial zones in Germany with a wide range of activities from handling all sorts of goods and logistics services to industrial production. There are many intermodal terminals in the Hamburg area. However, their capacity is highly utilized, to the extent that it is causing waiting time as well as high demands to quickly move loading units in a way that complicates logistics. Furthermore, there are restrictions on semi-trailers, as these cannot be stacked like containers, hence being less area efficient.

4. Terminal availability and prices in Denmark. There is a lack of open intermodal road/rail terminals in Denmark, hence competition is weak and the prices for using the terminals are high (way above similar terminals in Sweden, Germany, and Italy). When one actor dominates the market, other logistics operators might be effectively hindered to move goods from road to rail, as it might mean another lift, adding to costs. This prevents modal shift and risks the opportunity to strengthen the Copenhagen area as a hub for intermodal freight transport. The solution is not obvious, but a new, open terminal capacity would improve the situation and make intermodal road/rail transport more competitive, whether located in Høje Taastrup or elsewhere (for example in Køge Nord).

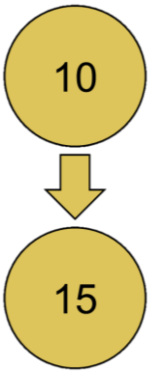
5. The railway Oslo-Gothenburg. The railway between two of the largest Nordic regions has major flaws. The running time is 6 hours 30 minutes to cover 350 km while road transport time is approximately 3 hours 30 minutes. The line speed is below 100 km/h on 50 % of the distance and there are steep gradients and length restrictions affecting cost efficiency very negatively (Sweco 2022; Trafikverket and Jernbanedirektoratet 2016 and 2023 and others).

6. The railway system in the Oslo region and the Alnabru terminal. The railway network in the Oslo region has severe capacity challenges because of large passenger flows as well as freight volumes. This leads to disturbances affecting transport quality negatively. The Alnabru terminal is the largest in the Nordic countries and plays an important role in Norwegian rail freight. The terminal has capacity constraints and must be further developed to promote a modal shift.

7. The Western Main Line in Sweden. It might be the most important railway in Sweden with large flows of both passengers and goods, but lack of capacity has deteriorated traffic quality, leading to disturbances and longer transport times. The part between Gothenburg and Alingsås needs four tracks as soon as possible (Sweco 2021; Trafikverket 2021 and others).

8. The Southern Main Line in Sweden. The government has cancelled the plans for a new high-speed rail network between Stockholm and Gothenburg/Malmö. One important benefit of that network was to ensure the necessary capacity for freight trains to/from the fixed link across the Öresund since the existing line would have fewer fast passenger trains. There is at the time of writing a great uncertainty about when that capacity will be available, although the need is widely recognized.

9. Train lengths in Sweden and Norway. As shown in chapter 5.5, longer and heavier trains have a large potential of increasing railway competitiveness. Current restrictions as well as lack of capacity are reducing railway competitiveness.



Category B

10. Hamburg - Lübeck - Puttgarden (Hinterlandanbindung FBQ). It is part of the state treaty between Germany and Denmark and is to be ready when the FBFL opens. The project includes new tracks, electrification, new passing stations, and an extension of passing tracks to 850 metres. Measures have mainly not started. However, this project is crucial for the success of FBFL and if it is not completed in 2029, it will be the most severe bottleneck in the STRING corridor.

11. Danish bottlenecks around Copenhagen. The new, improved railway from Copenhagen to the FBFL will add to existing bottlenecks. In Ringsted there are several railway crossings not grade-separated, meaning that trains must wait for each other. It is important to make it possible for trains from the Copenhagen area towards South Zealand and Hamburg to cross the trains from Odense towards Copenhagen without them having to wait for each other. This requires a track junction separated in height. When the FBFL opens, the need to solve this problem will increase noticeably. Otherwise, the possibilities for developing train traffic over the Great Belt or Fehmarn Belt will be limited. There is a similar situation in Ny Ellebjerg with conflicting train paths. If this is not solved, most freight trains will be forced to take the detour via the railway via Roskilde rather than the new line via Køge. There is also a need to study how to ensure sufficient railway capacity between Kastrup and Kalvebod, though passing tracks for freight trains are planned after Kalvebod and at the Copenhagen Airport station. There is an apparent need to increase capacity at Copenhagen Airport, but current plans to turn Swedish passenger trains at Copenhagen Airport to relieve the railway to Copenhagen Central is not beneficial for the integration of the Greater Copenhagen Area. These projects are prioritised in the Danish Infrastructure plan (Transportministeriet 2021b). The 2-track stretch from “Hvidovre fjern” to Høje Taastrup may also be a future bottleneck.

12. Swedish bottlenecks around Malmö. In the transport infrastructure plan for the period 2022-33, the Swedish Transport Administration suggested a package of capacity enhancing measures in and around Malmö. In the politically decided plan, that package was cancelled. There is also a need to study rail passings separated in height by Svågertorp and how to increase the capacity of the marshalling yard in Malmö, one of the three largest in Sweden. The marshalling yard in Malmö has serious constraints when it comes to handling longer trains, but also for instance crossing train paths (Trafikverket 2021 p.228).

13. The West Coast Line around Gothenburg. The West Coast Line is central for transport in the STRING corridor. South of Gothenburg, capacity constraints are obstructing the development of rail transport for passengers as well as freight.

14. ERTMS. The new European standard signalling system will, according to plans, have important benefits for freight transport. ERTMS will enable more efficient traffic management in real-time, increase average speed, reliability and capacity as well as reduce operating costs. Over time costs will be reduced if locomotives do not need to be equipped with interphases to several signal systems, and the education of drivers will be more favourable as well. Though the time schedules are vague, the system will not be fully developed in the STRING countries until earliest the mid-2030s.

15. Strategic redundancy across the Öresund. There is an obvious risk that the railway ferries between Trelleborg and Rostock will cease to operate, due to low profitability. Measures to increase railway competitiveness might improve the market conditions for the ferries as well, but the opening of the FBFL will shift transport to the fixed links. Many operators testify that redundancy is crucial for their operations. It would be troublesome to lose redundancy between Southern Sweden and Germany about at the same time as redundancy through Denmark is established. Although that alone might not determine whether to establish another fixed link across the Öresund, it is an argument to take into consideration. Other solutions might be possible but also legally and politically complicated, such as governmental subsidies for the railway ferries. Regarding the need for extra capacity across the Öresund to cope with future transport flows, most studies indicate that the existing fixed link will have enough capacity beyond 2040 (AFRY 2021).

6.7 Conclusions – Railway capacity

This chapter shows major capacity constraints in the rail network within and adjacent to the STRING corridor. Since these restrictions have a direct, negative impact on the most important factors for choosing a transport solution, it is crucial that they are addressed. Only then can the fixed link across the Fehmarn Belt give full effect. The expression that a chain is not stronger than its weakest link is never as relevant as it is to the railway system. FBFL creates a strong link in transport chains with many, weaker links. The situation is particularly serious in Germany, which is at the same time the destination, starting point or transit country for virtually all shipments relevant to the FBFL.

The situation is particularly serious in Germany, which is at the same time the destination, starting point or transit country for virtually all shipments relevant to the FBFL.

The report identifies two categories of infrastructure operations. The first category concerns capacity constraints, which already today prevent the transfer of goods from road to rail. The second category concerns challenges that will limit transfers in 2030, or earlier. Given the long lead times to improve the infrastructure, the categorization is not decisive, but all projects must be implemented urgently. One challenge is that the construction works risk leading to disruptions in rail traffic. Hence, there is a risk that it will get worse before it gets better.

There are strong reasons to learn from the German "Acceleration committee" and its recommendations, which have a clear focus on rapidly improving the situation (BMDV 2022c).

7. Recommendations

The analysis in this report results in clear conclusions. The tunnel under the Fehmarn Belt makes valuable contributions to strengthening rail freight in the STRING corridor, but it is not enough to lead to a substantial modal shift. It therefore appears to be a necessary, but not sufficient, instrument for an enhanced role for rail freight in the corridor. None of the most positive scenarios in this report indicate that the EU's ambitious targets for shifting from road to rail will be reached. A variety of complementary initiatives are needed to enable such a development fully utilize the FBFL. This report highlights the following measures and recommendations to strengthen rail freight in the STRING corridor:

- **Removing infrastructure bottlenecks is crucial for railway growth**. Capacity constraints have very negative consequences for all factors defining the competitiveness of transport modes.
- **Ensuring full train lengths and faster trains in the entire corridor and its connections will improve railway competitiveness**. It will increase rail freight transport capacity as well as enable more trains in the network.
- **The infrastructure standard in the TEN-T freight corridors is not sufficient, but rather represents a minimum standard**. The standard does not take into consideration capacity constraints hindering full utilization of the railway network, nor steep gradients (for example between Oslo and Gothenburg) and other bottlenecks.
- **There is a need for more terminals in Denmark, or multiple operators within each hub/terminal**, to ensure competition that contributes not only to railway cost efficiency, but also to increased reliability and capacity.
- **A level playing field between transport modes regarding fees and taxes is necessary**. This should ensure that all transport modes pay for their externalities.
- As road transport is expected to remain the dominant freight transport mode in the STRING corridor, any effort that minimizes greenhouse gas emissions from road vehicles would be just as important as paving the way for more rail freight. **Providing necessary infrastructure for zero or low-emission fuels is crucial** in this respect.
- **While railway transport has many advantages, sea transport could give significant contributions to the STRING corridor, primarily for transport to and from the corridor**. Railway bottlenecks could be partially relieved if cargo is transported by ship to a seaport closer to the origin or destination, before being transferred to rail transport (see for example Stelling et al 2019).

These recommendations should not be any surprise for decision-makers. The need for action is known, as are the solutions:

> *"In recent years, innovative companies have demonstrated that rail freight can operate reliably and be attractive to customers. However, many domestic rules and technical barriers still hinder performance. Rail freight needs serious boosting through increased capacity, strengthened cross-border coordination and cooperation between rail infrastructure managers, better overall management of the rail network, and the deployment of new technologies such as digital coupling and automation. The Commission will propose the revision of regulations governing Rail Freight Corridors and the TEN-T core network corridors. Integrating these corridors into 'European transport corridors', focusing on 'quick wins' like train length, loading gauge and improved operational rules, alongside the completion of key missing links and the adaptation of the core network so that it is fully freight capable, will strengthen the infrastructural dimension of our actions to promote intermodal transport. The Commission will propose to improve rules on rail capacity allocation in line with the ongoing project on the timetable redesign, to provide additional, flexible train paths." (European Commission 2020a p.9)*

Researchers and consultants have argued along the same line:

> *"To offer a competitive price and reliable service, a reduction in operating costs will be vital by implementing a number of measures, including operation of heavier and longer trains, wider loading gauge, higher average speed, and better utilization of wagon space and all assets. This will bring increased capacity, as well as better timetable planning, signalling systems and infrastructure improvements." (Islam et al 2016 p.17).*

One interesting initiative to promote railway competitiveness is the German "Acceleration commission" (BMDV 2022c). The commission has presented a total of 70 recommendations within five areas of action:

- Capacity-optimized use of the existing network and promotion of high-performance corridors.
- Accelerated implementation of small and medium-sized measures and electrification.
- Capacity-enhancing financing models.
- Optimized planning and construction.
- Essential legislative measures.

Although it is beyond the scope of this report to comment the recommendations, this kind of broad strategy is probably a good illustration of what it takes to greatly enhance rail performance and hence competitiveness.

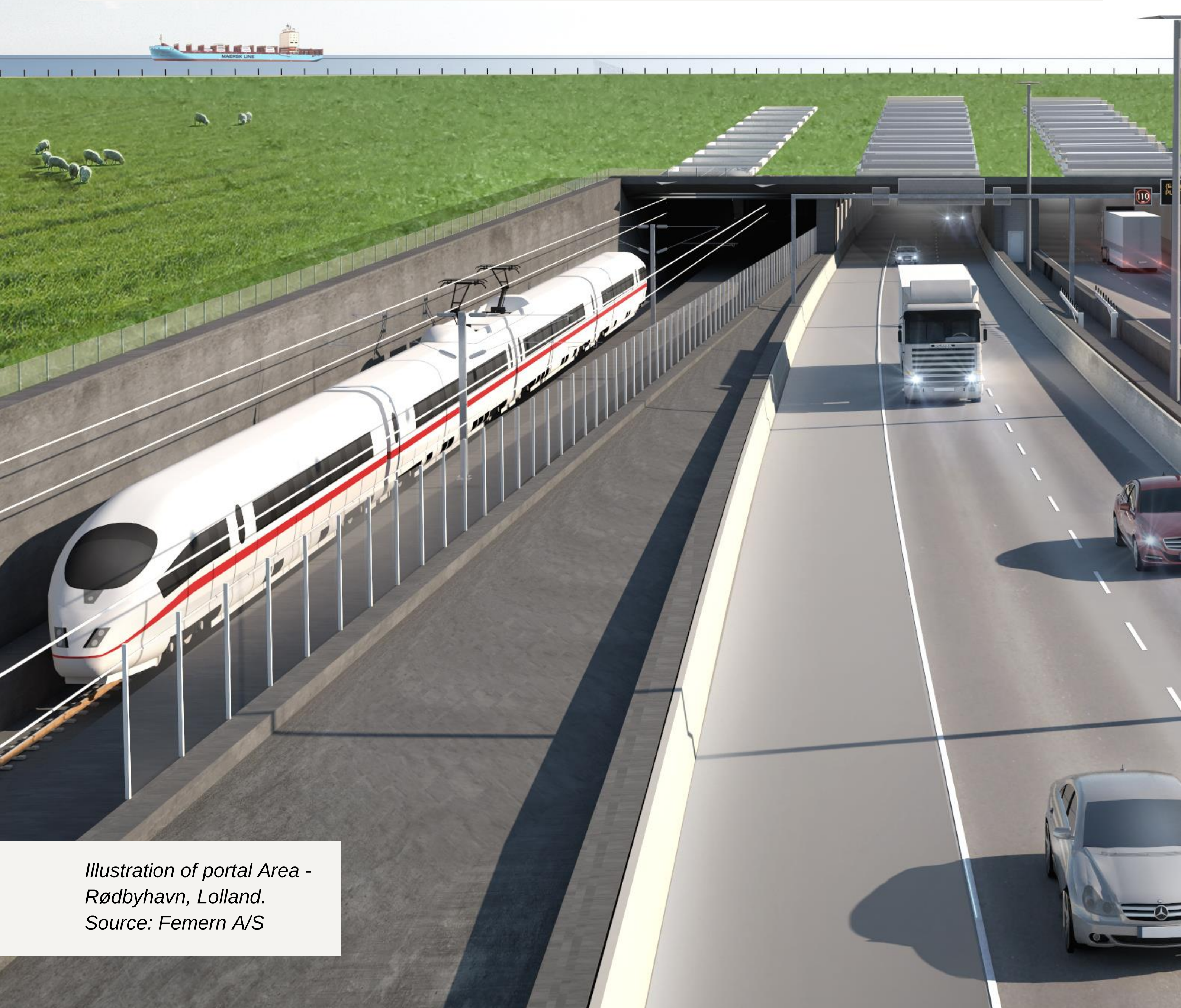


Illustration of portal Area - Rødbyhavn, Lolland. Source: Femern A/S

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Appendix 1. Eurostat Railway Statistics

Eurostat collects data on international freight transport by railway. The problem is that depending on the reporting country, the numbers differ greatly, see Table A1.

In recent years, it has also become very challenging to make those figures agree with data on railway transport on the Öresund fixed link and on railway ferries between Southern Sweden and Germany. They also do not correspond to numbers on transit volumes through Denmark. However, those transit volumes correspond very well with volumes on the Öresund fixed link when international Danish railway transport to/from Sweden and Norway are excluded.

It is far beyond the scope of this study to explain the differences and inconsistencies, but one possible explanation is that the operators count volumes double. A freight train might carry volumes from Sweden to Germany and Netherlands. When reporting loading in Sweden, the total volumes might be posted as German. Another possible explanation is that reporting includes or excludes volumes depending on whether the railway is used the entire distance from start to goal, or whether it is reloaded along the way. When moving goods from Sweden to Germany, a rail freight operator might use railway to transport a semi-trailer to a seaport in Sweden and then truck from the German seaport to the destination.

However, when looking at transit flows through Denmark as well as railway wagons and freight volumes on the ferries, the distinction is clearer, and it is much easier to confirm that the numbers add up and are plausible. Also, over time, those figures correlate well.

Table A1. Differences in railway volumes (ktonnes) depending on the country reporting. Sources: Eurostat[43]

Sweden reporting											
From	*To*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Germany	Sweden	2 346	2 568	2 249	2 415	2 555	2 465	2 691	2 554	2 416	2 643
Sweden	Germany	2 497	2 866	2 761	3 140	3 273	3 411	3 321	3 009	3 150	3 036
Total		**4 843**	**5 434**	**5 010**	**5 555**	**5 828**	**5 876**	**6 012**		**5 566**	**5 679**
Germany reporting											
From	*To*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Germany	Sweden	1 737	1 778	1 664	1 620	1 598	1 360	1 359	1 355	1 279	1 128
Sweden	Germany	2 173	2 179	2 025	2 130	2 038	1 794	1 552	1 534	1 551	1 358
Total		**3 910**	**3 957**	**3 689**	**3 750**	**3 636**	**3 154**	**2 911**	**2 889**	**2 830**	**2 486**
Difference		**933**	**1 477**	**1 321**	**1 805**	**2 192**	**2 722**	**3 101**		**2 736**	**3 193**
Denmark reporting											
From	*To*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Germany	Denmark	395	385	410	474	610	521	495	458	472	481
Denmark	Germany	76	58	94	199	165	92	99	114	82	136
Total		**471**	**443**	**504**	**673**	**775**	**613**	**594**	**572**	**554**	**617**
Germany reporting											
From	*To*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Germany	Denmark	631	504	656	753	756	659	602	1 452	1 205	1 144
Denmark	Germany	84	79	127	276	191	100	102	960	637	556
Total		**715**	**583**	**783**	**1 029**	**947**	**759**	**704**	**2 412**	**1 842**	**1 700**
Difference		**-244**	**-140**	**-279**	**-356**	**-172**	**-146**	**-110**		**-1 288**	**-1 083**

[43] Eurostat: International transport of goods from the reporting country to the unloading country. Accessed 23-03-05
Eurostat: International transport of goods from the loading country to the reporting country. Accessed 23-03-05
https://ec.europa.eu/eurostat/databrowser/view/RAIL_GO_INTCMGN/default/table?lang=en&category=rail.rail_go