

Transport and infrastructure connectivity bottleneck analysis for the stretch Oslo - Hamburg

for

STRING Network

prepared by

KombiConsult GmbH (lead partner)

Ramboll Norway

Ramboll Sweden

Ramboll Denmark

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1 Background of the Report

A high-quality transport infrastructure with sufficient capacity and which is managed efficiently is fundamental for the competitiveness of the economies of the Member States of the European Union (EU), the free movement of their populations, the EU integration, the cohesion of the standards of living and the integration with neighbouring countries.

The EU has been contributing to ensure this goal, amongst other instruments¹, through the trans-European transport network (TEN-T) policy. With the adoption of Regulation (EU) No 1315/2013 "on Union guidelines for the development of the trans-European transport network" in December 2013, a new approach entered into force. The primary objective of the new guidelines "is to establish a complete and integrated trans-European transport network, covering all Member States and regions and providing the basis for the balanced development of all transport modes in order to facilitate their respective advantages, thereby maximising the value added for Europe of the network".

The STRING Network between Oslo and Hamburg is made of four countries, eight regions, five cities, three metropolitan areas and represents about 14 million people which has the vision to create a global mega region leading to sustainable infrastructure to combat climate change while improving the lives of the citizens.

The STRING stretch is an integral part of the infrastructure of the TEN-T Core Network Corridor Scandinavian-Mediterranean (Scan-Med)² and already shows a high quality, today. However, and in particular with view on the envisaged completion of the Scan-Med corridor by 2030, still some gaps are expected to remain from today's point of view. The task is to define, map and describe the key infrastructure, identify transport bottlenecks, and propose recommendations what still needs to be done to eliminate the remaining bottlenecks on the STRING stretch between Oslo and Hamburg.

This report focuses on the current STRING Corridor, following the current alignment of the TEN-T Corridor Scan-Med and the membership within the STRING Consortium. It is however noted that with upcoming new CEF regulation, which shall come into force from 2021, it is expected that the Scan-Med Corridor between Oslo and Hamburg will be extended by one more route: in Fredericia/Taulov, the Jutland Corridor will be linked all the way up to Frederikshavn/Hirtshals.

¹ The White paper 2011 "Roadmap to a single European Transport Area – towards a competitive and resource efficient transport systems with the goal of "A 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport".

² The TEN-T Core Network Corridors are defined in the Regulation (EU) 1316/2013 together with the financial instruments ("Connecting Europe Facility – CEF") to support their completion by 2030.

2 The existing Infrastructure

The STRING stretch between Oslo and Hamburg is part of the current TEN-T Core Network Corridor Scan-Med and thus part of one of the crucial north south axes for the European economy. It connects Norway, the three EU Member States, Sweden, Denmark, and Germany, and links several major urban centres in those countries.

In terms of the analysed STRING network there are two different routes defined. From north to south between Oslo and Ringsted near Copenhagen they follow the same line, but are different between Denmark and Germany. One route goes via Fehmarn, and the other one via Jutland:

Via Jutland	via Fehmarn
Oslo – Gothenburg – Malmö – Copenhagen – Ringsted –	
– Fredericia/Taulov – Padborg/Flensburg – Hamburg	– Rodby – Fehmarn – Lübeck – Hamburg
This route has a length of about 1.350 km of main rail line and about 1.100 km of main road from node Oslo to node Hamburg.	This route has a length of about 1.100 km of main rail line and about 970 km of main road from node Oslo to node Hamburg.

The longer rail length on both the Fehmarn and Jutland route in comparison with road is due to different and longer lines than road and the fact that for instance around Malmö there are partly separated lines for freight and passenger traffic. Furthermore, around Copenhagen there are also partly two different railway lines.

Additionally, the section between Malmö and Trelleborg was analysed. This section has a length of about 30 km of main rail line and about 25 km of main road.

In total, and counting the overlapping parts of the different routes only once, the STRING stretch covers about 1.600 km of main rail lines and about 1.400 km of main road. A short overview of the before mentioned quantitative characteristics of the STRING stretch is provided in the following table.

Table 1: Main Characteristics of the STRING stretch

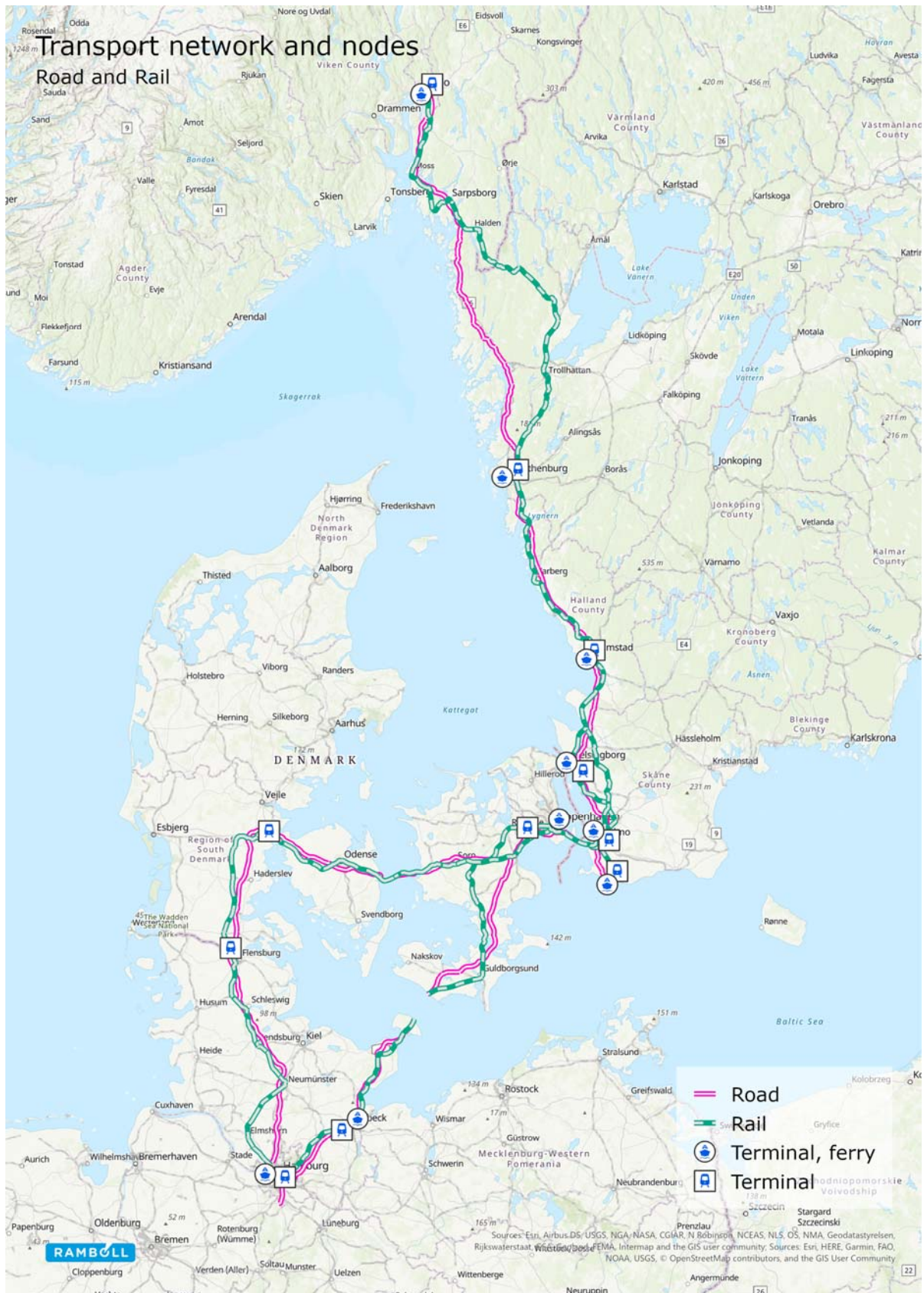
Mode \ Country	Rail*	Road*	Intermodal Terminals	Ports	Nodes
Norway	170 km	111 km	Oslo	Oslo	Oslo
Sweden	620 km	530 km	Gothenburg, Halmstad, Helsingborg, Malmö (2x), Trelleborg	Gothenburg, Halmstad, Helsingborg, Malmö**, Trelleborg	Gothenburg, Malmö, Trelleborg
Denmark	525 km	454 km	Copenhagen Taulov Padborg	Copenhagen**, Køge	Copenhagen, Odense, Fredericia
Germany	330 km	314 km	Lübeck (2x), Hamburg (5x)	Lübeck, Hamburg	Lübeck Hamburg
Total	1.644 km	1.406 km	17	9	9

* TEN-T core lines; figures rounded to full amounts; road length measured from node centre to node centre, actual length depends on starting point and interim stops; ** Copenhagen Malmö Ports managed by one company with installations in both countries. Chosen terminals, ports and nodes go beyond the TEN-T core and comprehensive definitions

Source: KombiConsult/Ramböll analysis

The map on the following page provides an overview of the infrastructure, while the infrastructure is described in the following chapters in detail. Though following two routes, the STRING stretch itself seems to be in a somewhat “isolated” manner, but it is part of a larger corridor and connected to further infrastructures geographically for all modes of transport which form a network. We have, however, maintained the STRING notion.

Figure 1: Schematic alignment of the STRING stretch



Source: Ramböll

Rail

The rail line on the STRING stretch is characterized by some historical and important railway links. The following table provides an overview of a few rail links, their names and their main function.

Table 2: Overview of several sections, their respective names and functions on the STRING stretch

Link	Name	Service function
Oslo – Kornsjö	Østfoldbanen	Main passenger and freight route Oslo – Gothenburg in Norway
Bryn – Alnabru	Hovedbanen	Regional and to some extent passenger train route; Connecting Alnabru terminal to Østfoldbanen
Ski – Sarpsborg	Indre Østfoldbanen, Østre linje	Regional passenger transport; Alternative route for freight trains on Østfoldbanen
Skälebol – Gothenburg	Norge-Vänerbanan	Main passenger and freight route Oslo – Gothenburg in Sweden
Partihallsområdet – Port of Gothenburg	Hamnbanan	Freight railway connection from/to port of Gothenburg and industries on Hisingen to the national railway system
Malmö – Trelleborg	Kontinentalbanan	32 km long railway line between Malmö and Trelleborg. At Malmö it is also part of the line between Malmö and Copenhagen. the passenger services only began in 2015 again after 40 years of no services.
Copenhagen – Korsør	Vestbanen	The line between Copenhagen and Fredericia/Taulov is one the main lines of the Danish railway network.
Nyborg – Fredericia	Fynske hovedbane	Built in the 19 centuries, the two railway lines across Zealand and Funen were connected in 1997 by Great Belt Fixed Link
Copenhagen – Hamburg	Fugleflugtslinjen	Historical transport corridor between Copenhagen and Hamburg via Fehmarn Belt

Source: KombiConsult/Ramböll analysis

Port of Gothenburg and the railroad terminal at Oslo (Alnabru) are identified as node infrastructure components on the TEN-T Scan-Med Corridor. Their inbound and outbound freight traffic is fed – to and from the main railway lines – by Hamnbanan and Hovedbanen, respectively. The latter is also used for regional and national passenger trains between Oslo and Lillestrøm/Eidsvoll.

The Oslo – Charlottenberg – Kil – Skälebol line is mainly used by freight trains between northern Sweden and Gothenburg. It also accommodates long-distance passenger trains between Stockholm

and Oslo as well as regional passenger trains. It is an alternative freight route between Oslo and Gothenburg.

A census in 2019 (15th of October 2019) showed that 109 trains served the main passenger and freight railway route (Oslo) – Kornsjö – Skälebol – Gothenburg in both directions, whereof 80% were passenger trains. Only 10 trains were in cross-border service, including six passenger trains, two freight trains between Oslo and Gothenburg, and two freight trains between Oslo and Trelleborg. Worth to mention is that closer to the urban nodes the traffic is much more intense. This shows the current analysis (see Table 6 and Table 7), as between Gothenburg and Malmö there are “just” 10 passenger trains per day and direction, and between Malmö and Copenhagen there are even 63 passenger trains per day and direction. On the Fehmarn route further south from Ringsted there are only regional trains running and the train frequency has been reduced since no train ferry services are offered anymore between Denmark and Germany. Consequently, the direct train Copenhagen – Hamburg has been re-routed via the Jutland route until opening of the Fehmern Belt Fixed Link. Thus, between Copenhagen and Rodby there are only five passenger trains per day and direction, and between Puttgarden and Hamburg there are 10 trains running per day and direction. As concerns the Jutland route between the Copenhagen, Odense and Fredericia/Taulov area there are a lot of passenger trains running, with 51 trains per day and direction between Copenhagen and Odense, and 45 trains per direction and day between Odense and Kolding at Fredericia/Kolding. The route between Kolding, Padborg/Flensburg and Hamburg is again not that much frequented, as there are only about 10 passenger trains running per day and direction. In addition, there is substantial freight train traffic on the Jutland route, including transit trains between Sweden and Germany and trains originating from the freight terminals in Taulov and Padborg.

Ferry

The connection on the Fehmarn STRING stretch between Denmark (Rødby) and Germany (Puttgarden) is currently a 19 km ferry link, which is part of the so-called “Vogelfluglinie” corridor (Fugleflugtslinjen in Danish) between Copenhagen and Hamburg. The ferries are operated by Scandlines and take 45 minutes, leaving almost every 40 minutes each and every day. Since 1997, as concerns the rail connection, diesel multiple-unit trains (ICE-TD, IC3) have been carried on the ferries until 14th December 2019, when the rail connection has been discontinued at all due to track works on the Danish side for the planned Fehmarn Belt Fixed Link. Thus, currently all trains running between Scandinavia and Germany take the route via Jutland over the Great Belt Fixed Link.

Alongside the STRING stretch there are also other ferry line services, offering passenger transport and truck transport for freight as well:

Table 3: Overview of ferry services between North-Western Germany and Scandinavia alongside the STRING stretch

Link	Transport time	Frequency
Oslo – Fredrikshavn	10 hours	1 x per day / direction
Oslo – Copenhagen	19 hours	1 x per day / direction
Oslo – Kiel	20 hours	10 x per week / direction
Gothenburg – Kiel	15 hours	5 x per week / direction
Helsingborg – Helsingør	20 minutes	55 per day / direction

Link	Transport time	Frequency
Malmö – Travemünde	9 hours	3 x per day / direction
Trelleborg – Travemünde	9 hours	3x - 4x per day / direction
Trelleborg – Rostock	6 hours	3 x per day / direction
Rødby – Puttgarden	45 minutes	36 x per day / direction
Gedser – Rostock	2 hours	10 x per day / direction

Source: KombiConsult/Ramböll analysis

Road

The corridor road through Norway and Sweden is part of the European route E6. Significant investments already helped upgrading the road infrastructure resulting in a continuous four-lane motorway between Oslo and Gothenburg in 2015. In effect, the E6 motorway has become the main transport route connecting the regions and cities to each other along the Western Scandinavia coast, and the most important crossing between Norway and Sweden both in terms of freight transport and passenger volumes. As evidenced in the freight transport study³ commissioned to Ramboll by Akershus and Oslo Municipality within the framework of the Scandinavian 8 Million City project⁴, in the period of 2004-2013, the total traffic across the Norway-Sweden border at the Svinesund Bridge increased by over 40% to almost 22.000 vehicles per day. Similarly, a 40% increase was noted for heavy transport as the daily traffic volume reached almost 2.500 vehicles. Lorries registered outside Scandinavia accounted for over half of all cargo transport. The Swedish traffic growth prognoses estimate the further increase of freight volumes in transit transported on roads towards and from the ports and airports in the Swedish part of Western Scandinavia by 20-30 million tonnes per year, whereas rail transport is not expected to grow significantly⁵. Close to 97% of all freights between Oslo and Gothenburg are transported by road, with over 70% of lorries returning empty.

At Gothenburg the E6 is “joined” by E20 (partly together with E45) until Malmö, where the E6 leaves towards Trelleborg.

Further via Fehmarn:

The E20 then goes through Malmö and Copenhagen to Køge. A project eliminating a significant bottleneck in the Copenhagen area was completed in 2018, namely the Development of the Køge Bugt Motorway. About 116.000 to 130.000 vehicles per day (both directions) are travelling on that section, with a heavy load transport share of about 11%. The project expanded the motorway south of Copenhagen from six to eight lanes, removing a bottleneck of 14 km. From Køge the road continues as E47 via the island Falster to Rødby on Lolland. Further from Rødby, on the opposite of the Fehmarn belt on the German mainland, the E47 leads until Lübeck. From there it starts the E22 to Hamburg. On the German section between Lübeck and Hamburg, the road traffic intensifies and a traffic census in 2015 counted about 85.000 cars per day (both directions) with a heavy load transport share of about 13 %. In the vicinity of Hamburg there are even about 94.000 cars per day.

³ Ramboll Sweden AB, 2013, Missing Link 2013. Godstransporter mellan Norge och Sverige - Resultat och analys av intervjuundersökning med chaufförer av tunga fordon på Svinesundsbron

⁴ <http://8millioncity.com/>

⁵ https://www.trafa.se/globalassets/rapporter/2016/rapport-2016_7_godstransporter-i-sverige---en-nulagesanalys.pdf

Further via Jutland:

Via Malmö and Copenhagen, the E20 goes further westwards via Fynen until Kolding. Several measures were already taken recently on the E20, including widening of E20 on western Funen between Middelfart and Odense V from 4 to 6 lanes. First section between Middelfart and Nørre Aaby was completed in 2014. Second section between Odense V and Aarup was completed in December 2020, and the final section between Aarup and Nørre Aaby is under construction and will be completed by the end of 2022. Furthermore, temporary measures, including upgrading safety lanes and interchanges near Kolding, have been implemented, in order to strengthen the road and increase the capacity. In the area near Kolding, where the E20 goes into the E45, the motorway carries near 100.000 vehicles per day (both directions). From Kolding the E45 goes all the way down until Hamburg. The E45 is an important transport axis connecting Scandinavian countries with Germany (Schleswig-Holstein and beyond) and other European countries further southwards. In Denmark the E45 goes all along from Frederikshavn in the North down to Padborg at the Danish-German border. In Germany the E45 is part of the motorway A7, which is the longest motorway in Germany and the second longest national continuous motorway in Europe. In particular in the Hamburg area with the double function for commuter, local and long-distance traffic it has a transport volume of about 150.000 vehicles per day. A significant improvement on a about 60 km long section on the A7 motorway between Bordsesholm and Hamburg has been achieved by extending the lanes from four to six lanes. Though with the realisation of the Fixed Fehmern Belt Link and a partly traffic shift, the part of the E45 via Denmark and northern Germany will maintain an important north-south axis. The importance of this north-south axis Hamburg - Fredericia/Taulov - Frederikshavn/Hirtshals will be further increased when the section from Fredericia/Taulov to Frederikshavn/Hirtshals is included in the Scan-Med Corridor in the near future.

Urban Nodes / Intermodal terminals

The STRING stretch covers eighteen intermodal terminals and five core urban nodes, in particular Oslo, Gothenburg, Malmö, Copenhagen and Hamburg, as well as other important and larger nodes. As regards modal and infrastructural interconnection between the Trans-European, regional and local transport networks, these “nodes” are of specific importance. As “multimodal” infrastructures they facilitate the transfer between modes and within modes for both passenger and freight traffic.

Intermodal – or rail/road – terminals as the main access points to market driven intermodal transport services are available in relatively high density and attain good quality levels along the STRING stretch. Six of the identified intermodal terminals on the STRING stretch are defined as core rail/road terminals of the Scan-Med corridor according to the TEN-T Regulation. At seven intermodal terminals, located in ports, there are also ferry connections available, which are in particular Gothenburg Arken, Halmstad, Helsingborg, Malmö, Trelleborg and Lübeck. Thus, they serve as link between ferry and respective rail or road hinterland connections from and to the ports. The terminal Gothenburg Arken was just officially opened at the beginning of 2018, and trucks do not have to take their path through the centre of Gothenburg anymore. Other terminals are located in or near sea container terminals, such as in Hamburg the rail/road container terminals in Altenwerder, Burchardkai, Tollerort and Eurokombi. As such they serve as interface between sea and rail hinterland container traffic. The following table shows some main characteristics of the beforementioned intermodal terminals.

Table 4: Main characteristics of the intermodal terminals on the STRING stretch

Country	Terminal	Modes Served			Rail tracks	Handling equipment	
						RMG	RS
NO	Oslo Alnabru*	Road	Rail	-	5 x 550 m 2 x 550 m 3 x 400 m	2	3
	Gothenburg Arken*	Road	Rail	Sea, Ferry	3 x 420 m 2 x 600 m	2	3
SE	Halmstad Port Container terminal	Road	Rail	Sea, Ferry	2 x 440 m	-	5***
	Helsingborg kombiterminal	Road	Rail	Ferry	4 x 650 m	-	2
	Helsingborg Port Kombiterminal	Road	Rail	Ferry	4 x 500 m	-	4
	Malmö Kombiterminal**	Road	Rail	-	4 x 750 m 2 x 350 m	2	4
	Malmö Port Kombiterminal**	Road	Rail	Sea, Ferry	2 x 850 m	-	5***
	Trelleborg Port, kombiterminal	Road	Rail	Ferry	2 x 500 m	-	2
	København (Høje-Taastrup)*	Road	Rail	-	4 x 400 m	-	2
DK	Taulov	Road	Rail	-	1 x 700 m 2 x 500 m	-	2
	Padborg	Road	Rail	-	1 x 490 m 1 x 460 m	-	2
	Lübeck CTL	Road	Rail	Short Sea	4 x 340 m	-	5
DE	Lübeck Skandinavienkai*	Road	Rail	Ferry	5 x 600 m 1 x 200 m	2	-
	Hamburg Altenwerder	Road	Rail	Sea	9 x 700 m	4	-
	Hamburg-Billwerder*	Road	Rail	-	4 x 720 m 4 x 620 m 4 x 575 m	7	-
	Hamburg Burchardkai	Road	Rail	Sea	10 x 740 m	4	-
	Hamburg Eurokombi	Road	Rail	Sea	10 x 720 m 1 x 640 m	8	2
	Hamburg Tollerort	Road	Rail	Sea	5 x 720	3	-

RMG = Rail Mounted Gantry Cranes; RS = Reachstacker; * Core RRT terminals defined by TEN-T Regulation; ** Connected to Malmö marshalling yard with two rail tracks allowing for 835 meter long freight trains, *** Estimated visually by Google maps

Source: KombiConsult/Ramböll analysis

3 The Bottlenecks

3.1 Definition of Bottlenecks

Transport and infrastructure bottlenecks can affect the normal flow of transportation, causing unnecessarily long travel times, delays, congestions, costs, etc. In order to understand where bottlenecks exist, it is important first to clarify what are transport bottlenecks, what kind of bottlenecks exist, and to cluster them.

Besides physical infrastructure restrictions, also administrative, regulatory and operational bottlenecks can have a negative effect on the flow of transportation. Especially on cross border sections on rail there can occur many hindrances other than just physical infrastructure restrictions. For the purposes of this study, we use the “bottleneck” definition of the TEN-T Regulation, which is – according to Article 2 (q) – the following:

“‘bottleneck’ means a physical, technical or functional barrier which leads to a system break affecting the continuity of long-distance or cross-border flows and which can be surmounted by creating new infrastructure or substantially upgrading existing infrastructure that could bring significant improvements which will solve the bottleneck constraints;”.

Following this definition, we clustered the bottlenecks in the three main groups of physical, technical and functional barrier and assigned subcategories to them (see Figure 2).

Figure 2: Bottleneck clusters

Bottleneck	Subcategory
Physical barrier	Missing link
	Insufficient link
	Missing connectivity
Technical barrier	No electrification
	Only single lanes / tracks
	Insufficient tunnel heights
	Insufficient loading gauge
	Insufficient maximum permitted train length
	Insufficient maximum speed
	Weight restrictions
	Insufficient capacity
Functional barrier	Different / outdated traffic systems
	No intermodality
	Lack of digitalisation
	No transport management system
	Customs regulation
	Cross border regulations
	Personnel planning (RU's)

Source: KombiConsult/Ramböll analysis

3.2 Non-Compliance with TEN-T Regulation Requirements

One of the key elements for the identification of the bottlenecks is a comparison of the parameters of the existing infrastructure and its current status with the requirements of the TEN-T Regulation (EU) 1315/2013 to be achieved by the year 2030.

Article 4 of the TEN-T Regulation describes the objectives of the Trans-European Transport Network. It shall strengthen the social, economic and territorial cohesion of the European Union. The aim is to create a single European transport area, which is efficient and sustainable to increase the benefits for its users and to support inclusive growth. At the end of 2014, within the framework of the TEN-T corridor studies the Member States of the defined nine Core Network Corridors agreed a list of specific objectives, additionally to the ones in the regulation, which have to be met by 2030 at the latest (see Table 5).

These objectives have been transferred into so-called Key Performance Indicators (KPIs) that apply to all nine core network corridors. The KPIs allow measuring and monitoring the extent to which target values are realized. The values presented in the following tables represent the length of the compliant infrastructure sections or the number of compliant nodes, compared to the overall length or number of nodes. Other persisting bottlenecks and missing links are described in the subsequent chapter.

Rail compliance

The following table compares the current compliance situation of the STRING stretch rail network with the status that shall be achieved by 2030 according to the TEN-T Regulation. Only the existing rail lines have been taken into account, thus, the part of the planned Fehmarn Belt Fixed Link itself is not included in these calculations, yet. We expect that the new rail line, once completed, will also comply with the EU targets.

Table 5: Current compliance of the STRING stretch with TEN-T rail requirements, status 2020

	Track gauge	Traction	N° of tracks	Line speed	Axle load	Train length	ERTMS In operation	
Targets \ Country	1,435 m	All lines electrified	double track	≥ 100 km/h	≥ 22,5 t	≥ 740 m	ETCS	GSM-R
NO	100%	100%	38%	61%	100%	0%	0%	100%
SE	100%	100%	67%	100%	100%	64%	0%	100%
DK	100%	77%	95%	100%	100%	100%	12%	100%
DE	100%	74%	74%	96%	96%	100%	0%	100%
Total*	100%	88%	74%	95%	99%	77%	4%	100%

* Due to different length (weighting) of the sections, the total percentage is not the average of the individual country figures; Source: KombiConsult/Ramböll analysis

Three of the eight (freight) railway related targets show high compliance values as measured in November 2020, two targets show mid and one low compliance, and only the requirements of standard track gauge of 1,435 m and lines providing GSM-R is generally 100% fulfilled. Thus, six EU-targets are “bottlenecks” as follows in detail:

Electrification: The STRING stretch rail lines are electrified to about 88%. As in Norway and Sweden all lines are electrified, non-electrified sections are located in Denmark and Germany, in particular on the northern and southern access routes to the planned Fehmarn Belt Fixed Link, namely the sections Ringsted – Rødby and Puttgarden - Bad Schwartau. Thus, only Diesel passenger trains are running on these sections currently.

Number of tracks: As oncoming trains must wait for each other at the crossing points, single-track sections generally allow lower line speed, lower frequencies and are less resilient in case of disturbances (traffic delays as well as maintenance and incidents). With 26% non-compliance, about 430 km of the Oslo – Hamburg link have a capacity constraint due to single-track. In Norway, though two parts have just been updated to double-tracks already, in particular on the sections Ski – Sandbukta and Såstad – Haug, the rest of the Østfold line between Sandbukta and Kornsjø (Norwegian-Swedish) border is still single-track with about 100 km total length. Additionally, there are two sections of the Norway link with critical gradients above 12.5‰. It is Brynsbakken (in Oslo, northbound), and Tistedalen (southbound), between Halden and the Swedish border, both with 25‰ gradient⁶. In Sweden, further south from Halden, from Kornsjö to Öxnered, a double-track line of about 100 km is missing, and between Ängelholm and Arlov (via Åstorp) a section of about 80 km. On the West Coast railway between Maria and Helsingborg is the remaining single-track sections between Malmö and Gothenburg. On the route between Malmö and Trelleborg, almost the whole section only provides single-track. Conversely, in Denmark between Høje-Taastrup and Roskilde, there are even four tracks. But further south about 30 km between Vordingborg and Nykøbing Falster does only provide single-track, and in Germany about 85 km on the southern access to the Fehmarn Belt between Puttgarden and Bad Schwartau, near Lübeck. Via Jutland in Denmark between Tinglev and Padborg there is a single-track section of around 11 km.

Line speed: Mostly gradients (up to 25 ‰) and tight curves limit the maximum speed, but also frequent traffic close to large cities and points with lower speed, e.g. due to noise protection. Thus, the design speed and, even more, the operating speed can vary from section to section, and can be even lower than 100 km/h on particular points. Theoretically, almost the entire STRING stretch with about 95% compliance provides an average design line speed of at least 100 km/h, with only a non-compliant section of about 70 km south of Oslo and two smaller sections in Germany on the route via Jutland near Flensburg and Rendsburg. The slower section at Rendsburg is due to the fact that the rail line has to overcome a bridge over the Kiel Canal (Nord-Ostsee-Kanal) with a height of 42 metres and in order to maintain the train station near the canal a loop was built to be able to elevate to the bridge (Rendsburger Schleife). The line maximum operating speed on the whole STRING section varies between 100 and 250 km/h. In Norway, the highest speed is at 160 km/h, but average design line speed varies between 70 and 140 km/h. In Sweden, the main part has an average line speed of 160 – 250 km/h with some short sections at 70 km/h, or even shorter sections where the line speed is even limited to 40 km/h. Nevertheless, what is more interesting than a theoretical design line speed and the possibility for trains to run with over 100 km/h, is the “real” scheduled travel time from point to point, as can be seen in Table 6 and Table 7.

Operational speed of passenger trains via Fehmarn:

According to the official internet schedules of the railway undertakings carrying out the respective services⁷, the average train speed for the train services offered on the section between Oslo and

⁶ https://ec.europa.eu/transport/sites/transport/files/work_plan_wpIII.pdf

⁷ Official timetables of the railway undertakings, 28.08.2020 and 27.11.2020

Malmö is quite higher than on sections southwards, but still below 100 km/h in average. Theoretically, when summarising the different travel times between the nodes on the route from Oslo to Hamburg via Fehmarn, it would take about 13,5 hours, taking any waiting times on the interchange stations not into account. This results in an average operating speed of about 75 km/h, which is quite below even the envisaged 100 km/h for freight.

Table 6: Travel times for passenger trains on the route Oslo – Hamburg 2020 via Fehmarn

Section	Ø Travel time	Distance	Speed	Frequency / trains	
	hh:mm	km	km/h	trains/day*	Type
Oslo					
Gothenborg	03:30	342	98	10	direct trains
Malmö	03:05	300	97	20	direct trains
Copenhagen	00:50	40	48	63	direct trains
Rødby	02:50	170	60	5	2 train changes
Puttgarden	00:45	19	25	36	direct ferry*
Hamburg	02:40	157	59	10	1 train change
Total / Ø	13:40	1.028	75		

* trains per day and direction

Source: KombiConsult/Ramböll analysis

Operational speed of passenger trains via Jutland:

When summarising the different travel times between the nodes on the route from Oslo to Hamburg via Jutland, it would take about 12,5 hours, taking any waiting times on the interchange stations also not into account (see Table 7). So, as things stand currently before opening of the Fehmarn Belt Fixed Link, the route is one hour quicker than via Fehmarn, though it is over 200 km longer. After the opening of the Fehmarn Belt Fixed Link this ratio will change. Nevertheless, a hypothetical journey of 12,5 hours results in an average operating speed of at least about 95 km/h, which is indeed again slightly below the envisaged 100 km/h for freight, and, at present, considerably faster than via Fehmarn. This shows very well the difference between current status of the infrastructure of the two routes. The route via Fehmarn lacks a fixed link and has very low sections, in particular on the northern and southern access routes from and to the Fehmarn belt between Ringsted and Hamburg, while the route via Jutland is already a continuous railway line and generally well developed. For instance, between Copenhagen and Hamburg, where a continuous railway connection via Jutland is available, it would take 4:40 hours, resulting in an average speed of about 111 km per hour for overcoming the distance of 520 km (see Table 8).

Table 7: Travel times for passenger trains on the route Oslo – Hamburg 2020 via Jutland

Section	Ø Travel time	Distance	Speed	Frequency / trains	
	hh:mm	km	km/h	trains/day*	Type
Oslo					
Gothenborg	03:30	342	98	10	direct trains
Malmö	03:05	300	97	20	direct trains
Copenhagen	00:50	40	48	63	direct trains
Odense	01:26	170	119	51	direct trains
Kolding	00:44	70	95	45	direct trains / 1 train change
Padborg	00:51	100	118	11	direct trains
Hamburg	02:14	178	80	9	direct trains / 1-2 train change
Total / Ø	12:40	1.200	95		

* trains per day and direction

Table 8: Travel times for a continuous passenger trains on the route Copenhagen – Hamburg 2020 via Jutland

Section	Ø Travel time	Distance	Speed	Frequency / trains	
	hh:mm	km	km/h	trains/day*	Type
Copenhagen					
Hamburg	04:40	518	111	7	direct trains

* trains per day and direction

Freight trains:

As one might expect, the travel time for freight trains generally lasts longer. Travel time for freight trains e.g., between Oslo and Gothenborg is about nine hours, including waiting times at the border crossing points, which is more than twice as long as a passenger train may need for the same distance. As for truck transport, the distance can be covered in three and a half hours, which is comparable to the travel time of a passenger train. For the transport of intermodal loading units from Oslo to Hamburg, it would take about two days, as there is no direct shuttle train connection between Oslo and Hamburg and the transport would be routed via gateways, including a ferry service. This means an average commercial speed of only 20 km/h. The reasons for this are two main factors: the pure “speed” of the train and the time loss at the interchanging points. For the very low average speed on the freight train run itself there can be many reasons, for instance it is because the trains often have a lower priority when scheduling, they often have to wait for (express or faster) passenger trains passing by, there are long border procedures, train driver changes, etc. The interchanging points are time consuming because there are waiting times between the different schedules for the train and ferry connections, and also buffers in the intermodal terminals between the times of start/arrival of the

train and loading/unloading of the train, that are needed e.g., for shunting, train composition, security checks, etc.

Table 9: Travel times for an intermodal train connection Oslo-Hamburg 2020 via ferry

Section	Schedule**			Travel time d:hh:mm	Distance* km	Speed km / h	Type
	from /to	Day	Time				
Oslo Alnabru Malmö hamn Kombi	from	Sa	12:00	18:00	630	35	Train
	to	So	06:00	04:00			
Malmö hamn Kombi Lübeck Skandinavienkai	from	So	10:00	09:00	313	35	Ferry
	to	So	19:00	16:40			
Lübeck Skandinavienkai Hamburg Billwerder Ubf	from	Mo	11:40	03:20	85	25	Train
	to	Mo	15:00				
Total / Ø				2:03:00	1.028	20	8 connections p. week

Source: kombiverkehr.de

* for comparison, distance was set equal to theoretical rail distance via Fehmarn Belt for passenger train connection

** from = end of loading time, to = time of availability

Source: KombiConsult/Ramböll analysis

Intermodal train connection via Jutland:

To compare the situation with the Jutland route, we picked up a train connection offered by Kombiverkehr between Copenhagen and Hamburg via Jutland. Though still not as favourable in terms of travel time as it is for passenger trains, the situation and thus the speed on the route via Jutland is currently quite better than via Fehmarn, where no intermodal trains are running at all and are routed via Jutland or the Malmö – Lübeck ferry connection, resulting in an average speed of at least 31 km/h for the section between the Høje Taastrup terminal and the terminal in Hamburg Billwerder.

Table 10: Travel times for an intermodal train connection Copenhagen-Hamburg 2020 via Jutland

Section	Schedule*			Travel time d:hh:mm	Distance km	Speed km / h	Type
	from /to	Day	Time				
Høje Taastrup KT Taulov KT	from	Mi	19:00	04:20	200	46	Train
	to	Mi	23:20	04:10			
Taulov KT Hamburg Billwerder Ubf	from	Do	03:30	07:45	305	39	Train
	to	Do	11:15				
Total / Ø				0:16:15	505	31	4 connections p. week

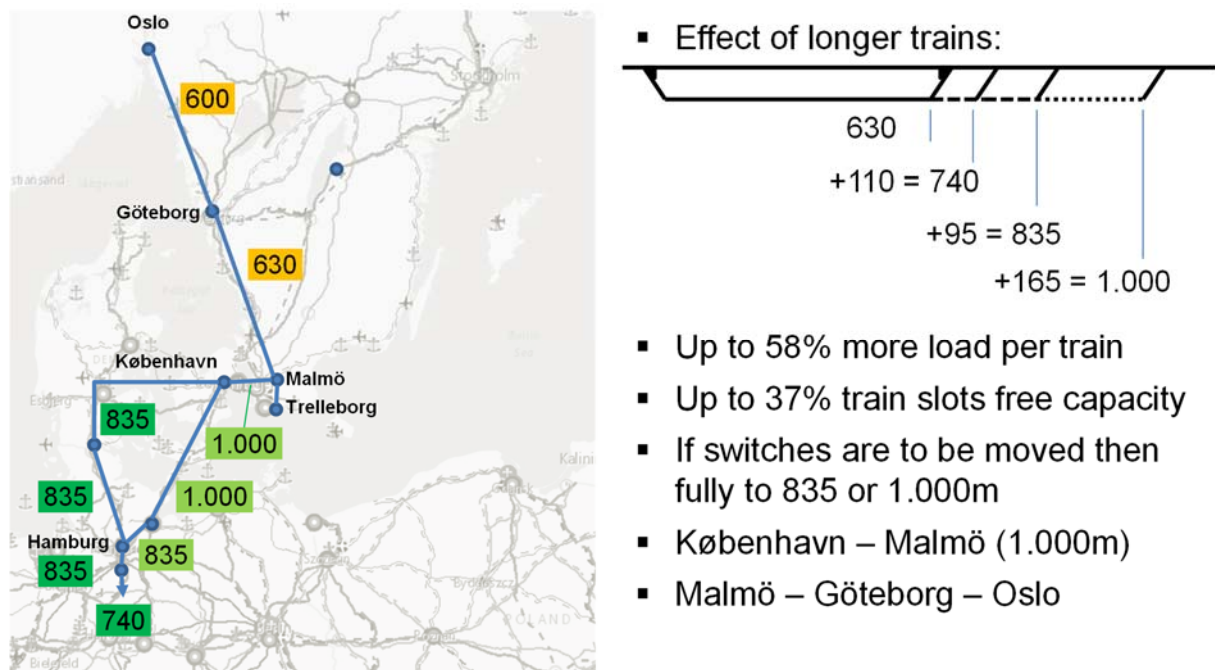
Source: kombiverkehr.de

* from = end of loading time, to = time of availability

Axle load: Almost the whole corridor provides for an axle load of at least 22.5 tonnes already today. Non-compliant section is only on the southern access routes to the planned Fehmarn Belt Fixed Link in Germany between Puttgarden and Großenbrode with about 15 km length.

Train length: The required maximum permitted length of freight trains set by the European Commission is 740 meters, including locomotive(s). Thereby, the possible train length on a railway track depends on various parameters such as signalling system, operating speed, inclination, length of sidings, traffic density, etc. Freight train length of 740 m is permitted on about 77% on the STRING stretch, which is at least more than two third. The lack of providing 740 m trains concerns mainly Norway and Sweden. This is due to changes in the Network statements: In Norway, BANE NOR cancelled the chapter on permitted train lengths in the Network Statement 2018 (valid from December 2017) onwards; Thus, neither standard nor line specific values are available anymore and therefore, the compliance of those corridor sections has been classified as below 740 m or even unknown. Sweden reduced the maximum permitted train length from 880 m (2014) to 630 m as standard value, thus also in general below the requirement to provide 740 m trains. Denmark and Germany provide train length for 740 m trains in general. Despite the non-compliance towards the requirements of the TEN-T Regulation, the following Figure 3 shows an overview of the different approaches and thus the subsequent dilemma, when the possible train length is not harmonised between neighbouring countries. As e.g., in Denmark with the highest value and the train length may be up to 1.000 m, the surrounding countries are quite lower. Thus, even if one country allows longer trains, with lower train lengths in the neighbouring countries on route it is impossible for international trains to use the longest length possible at all.

Figure 3: Overview of the possible train length and its effects of longer trains



Source: KombiConsult analysis

Another issue is the comparison of the development of the train and truck length in the EU and in the STRING countries, in particular Sweden. Whereas the train length in Sweden nowadays is, according to the network statement, even under the EU standard, the possible length for trucks in Sweden is

about 35% longer as the EU standard of 18.75 m. The gap between EU standard for rail and truck even gets worse in future, if the plans for 34,5 m trucks are continued, while the length for trains “only” shall reach the EU standard of 740 m. Although there are good arguments for longer (and heavier) lorries, meaning more freight can be transported with each lorry and this may reduce the number of lorries and thus less congestions and air pollution/energy consumption, this may jeopardize the overall goal to shift more freight from road to rail. If the “longer lorries” strategy is continued it is worth to agree measures making also “longer trains” possible.

ERTMS: ERTMS is made of two components: GSM-R for which 100% of the lines are equipped, and ETCS which is applied on only 4% of the STRING stretch rail lines, in particular only in Denmark. In all the other countries the rail lines on the STRING stretch are without ETCS.

The above infrastructural bottlenecks have its impact on the overall travel and transport conditions and performance, and affect supply chains, commuters, long-distance travellers along and within the STRING stretch between Oslo and Hamburg. First, they result in a lower railway connectivity and longer travel times. Secondly, they deteriorate the positive environmental effects expected from the railway system vs road in the STRING geography.

In effect, the infrastructural bottlenecks hinder territorial cohesion in the entire megaregion and may prevent reaping of full cross-border integration benefits in particular out of the Fehmarn Belt Fixed Link investment. In the absence of high-standard rail infrastructure, there is a risk that increasing freight flows are to enter and exit the STRING region by road.

[illegible]

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Road compliance

The following table compares the current compliance situation of the STRING stretch road network with the status that shall be achieved by 2030 according to the TEN-T Regulation. In contrast to rail, for road there are only two requirements highlighted: “Express road / motorway” and the “Availability of clean fuels”. According to the regulation, “clean fuels” means fuels which serve, at least partly, as a substitute for fossil oil sources in the supply of energy to transport, contribute to its decarbonisation and enhance the environmental performance of the transport sector, such as electricity, hydrogen (H₂), biofuels (liquids), synthetic fuels, methane (natural gas (CNG and LNG) and biomethane), and liquefied petroleum gas (LPG).

Table 11: Current compliance of the STRING stretch with TEN-T road requirements, status 2020

Targets	Express road / motorway	Availability of clean fuels
No	100%	100%
SE	100%	100%
DK	100%	81%
DE	94%	94%
Total	99%	92%

Source: Ramböll/KombiConsult analysis

Express road / motorway

In terms of the requirement for road to be classified as express road or motorway, the existing network is compliant to 99%. The remaining non-compliant sections are in Sweden, a small section through Trelleborg to the port, and in Germany, in particular the southern access to the Fehmarn Belt Fixed Link with a section of about 20 km.

Travel time via Fehmarn:

The travel time between Oslo and Hamburg via Fehmarn would be about 11:30 hours by car. The slowest part of the travel is the ferry connection between Denmark and Germany, where waiting times for the ferry are not even considered in the calculation. But also, the short section between Malmö and Copenhagen via the Öresund bridge is relatively slow. For a travel by bus from Oslo to Hamburg, when summarising the different sections from node to node, it would take about 13:30 hours, theoretically. But, according to the schedule, a travel by bus on the whole route from Oslo to Hamburg actually takes about 14:30 hours, which is including standing times at the interchange points. Bus transport between the different nodes can be very frequent with up to 23 departures per day in one way e.g., on the section between Oslo and Gothenburg, and, on the other side, can be very low e.g. on the section between Copenhagen and Lübeck, where there is very little or during winter season even no bus service at all on some parts.

Table 12: Travel times by car and bus 2020 via Fehmarn

	by car			by bus		
	Travel time hh:mm	Distance km	Speed km/h	Travel time hh:mm	Distance km	Speed km/h
Oslo						
Gothenborg	03:30	290	83	03:40	290	79
Malmö	02:55	280	96	03:10	280	88
Copenhagen	00:45	45	60	01:05	45	42
Rødby	01:45	180	103	02:45	180	65
Puttgarden	00:45	20	27	00:45	20	27
Hamburg	01:45	170	97	02:10	170	78
Total	11:25	985	86	13:35	985	73
Total*	10:45	985	92	14:30	985	68

Source: googlemaps, flixbus.de, Kombiconsult/Ramböll analysis

* in total from Oslo to Hamburg, for bus: connection offered by flixbus without consideration of route

Travel time via Jutland:

The travel time between Oslo and Hamburg via Jutland would be about 13:00 hours by car, summarising the different sections on the route. As it is about 130 km longer than via Fehmarn, it thus takes about one and a half hour longer. Interestingly, when calculating a run-through, it is with 11:15 hours almost equal to the estimated travel time via Fehmarn.

Table 13: Travel times by car via Jutland

	by car		
	Travel time hh:mm	Distance km	Speed km/h
Oslo			
	03:30	290	83
Gothenborg			
	02:55	280	96
Malmö			
	00:45	45	60
Copenhagen			
	01:55	170	89
Odense			
	01:50	150	82
Padborg			
	02:10	170	78
Hamburg			
Total	13:05	1.105	84
Total*	11:15	1.105	98

Source: googlemaps, flixbus.de, Kombiconsult/Ramböll analysis

* in total from Oslo to Hamburg, including standing times

Clean fuels

The TEN-T Regulation requires an availability of clean fuels along corridor roads which to date is achieved a rate of 92% on the STRING stretch. Thus, clean fuel is at least available in each country. But here we have to point out that the availability was measured in a way that stations do not necessarily have to be directly on the route. They could be placed in the closer environment of the motorway. Also, the stations are a mixture of stations for electricity or other clean fuels according to the TEN-T Regulation, such as Compresses Natural Gas (CNG) and Liquefied Natural Gas (LNG). Thus, for a road trip via one particular clean fuel the picture would be a bit different. Nevertheless, the availability of clean fuels on the corridor is relatively good and there are certain measures to improve the situation on the corridor for the availability of clean fuels. As concerns the usage of natural gas, CNG is the most widely used technique to store natural gas in vehicles and commonly used by passenger cars, while LNG is more used by trucks and busses. Even though it is a current TEN-T requirement to count CNG and LNG as clean fuels, to use natural gas as alternative fuels can also be seen as critical, as it is not renewable nor CO₂ neutral. For clean fuels in terms of electricity, e.g. project MECOR under the patronage of the of Swedish and Danish governments, achieved the availability of clean fuels connecting the two urban nodes of Malmö and Copenhagen as multimodal e-Mobility hubs. In Denmark electricity is the most common type of clean fuel. Recently, the GREAT project, which originated from STRING and was CEF-financed, has deployed 69 new fast chargers in Sweden, Denmark and northern Germany alongside the TEN-T infrastructure. What may hinder the development or the usage of electric vehicles (EV) on a corridor like STRING with many country or network borders may be other technical barriers, such as the lack of a harmonized EV-roaming, in order to allow any electric vehicle driver to charge at any charging station. Additionally, EV-roaming may help by providing

transparent information about charging stations and prices, which is also a substantial prerequisite for convincing people using electrical vehicles.

Intermodal terminal compliance

Regulation (EU) 1315/2013 directly requires Rail-Road terminals to be capable of for the transshipment of intermodal transport units and to be open for all operators.

The requirements of “Electrified train accessibility” and “740 m train terminal accessibility” are no direct requirements according to the TEN-T Regulation, but the requirements set for the rail network itself make it necessary also for terminals to comply with those provisions and has therefore been included as requirements, both in the Scan-Med Study supporting the European Coordinator and this analysis.

Table 14: Current compliance of STRING intermodal terminals with TEN-T rail/road terminal requirements, status 2020

	Intermodal terminal	Open to all operators	Capability of intermodal transshipment	Electrified train accessibility	740m train terminal accessibility
NO	Oslo Alnabru	Yes	Yes	yes	No
	Gothenburg Arken	Yes	Yes	Yes	No
	Halmstad	Yes	Yes	No	No
	Helsingborg kombiterminal	Yes	Yes	No	No
SE	Helsingborg Port Kombiterminal	yes	Yes	Yes	No
	Malmö Kombiterminal	Yes	Yes	Yes	Yes
	Malmö Port Kombiterminal	Yes	No	No	Yes
	Trelleborg Port Kombiterminal	Yes	Yes	Yes	No
DK	København (Høje-Taastrup)	Yes	Yes	No	No
	Taulov	Yes	Yes	No	No
	Padborg	Yes	Yes	Yes	No
	Lübeck CTL	Yes	Yes	No	No
DE	Lübeck Skandinavienkai	Yes	Yes	No	No
	Hamburg Altenwerder	Yes	No	No	No
	Hamburg-Billwerder	Yes	Yes	Yes	No
	Hamburg Buchardkai	Yes	No	No	Yes
	Hamburg Eurokombi	Yes	No	No	No
	Hamburg Tollerort	Yes	No	No	No
Total Compliance		All 100%	13 of 18 72%	7 of 18 39%	3 of 18 17%

*740 m train accessibility means that the terminals can offer handling tracks of at least 740 m
Source: KombiConsult/Ramböll analysis

Generally, all intermodal terminals belonging to the STRING stretch provide discrimination-free access for their users and, except of the four terminals located in the sea container terminals in Hamburg and the one in Malmö Port, which are focused on container hinterland traffic and thus generally handling only maritime containers, qualified handling equipment for all types of intermodal loading units.

The largest challenge for the present sites is that for only seven of the terminals the connection to rail infrastructure is electrified and for only three terminals it does allow directly the handling of 740 m trains. Hence, it does not correspond to the requirements of market-driven transport services and needs urgent improvement. 740 m train accessibility hereby means that the terminals itself can offer handling tracks of that length and thus can avoid shunting for serving intermodal trains of 740 m. Nevertheless, five other terminals offer handling tracks of at least 700 m and are close to the 740 m requirement.

Terminal management systems are widely used to provide real-time information on the operational situation in the terminal and for data exchange with connected transport mode operators (railway undertakings, intermodal operators and forwarders). ICT system implementation is a field where improvement is needed by the owners or operators of the respective sites. If it comes to public financing, the public entities should ensure that the ICT systems fulfil the requirements of Articles 28(1)(b) and 29(c) of the TEN-T Regulation in the strict sense.

3.3 Further Identified Bottlenecks

However, there are other factors beyond the requirements set in the TEN-T Regulation. In addition to that, infrastructure may be missing (“missing link”), its capacity may be limited (“bottleneck”) though corresponding already to the TEN-T requirements, or other physical and technical barriers which may hamper the continuous flow of passengers and freight across the STRING stretch infrastructure have to be considered. Thus, the objective of this task is the identification and analysis of EU and other regional or local studies, relevant policy actions, existing and planned projects in terms of the functioning and the further development of the STRING stretch.

As an outcome of the compliance analysis with the TEN-T Regulation and further information and data on the rail and road infrastructure of the STRING stretch, a bunch of bottlenecks could be identified. In particular we identified 29 rail bottlenecks, 12 road bottlenecks, 16 rail/road terminal bottlenecks, one specific port / maritime bottleneck, and a mixture of bottlenecks at rail border crossings.

Rail bottlenecks

The OECD Territorial Review Report on the Megaregion of Western Scandinavia⁸ positions this geographical area as a major corridor for freight, and e.g. its section between Oslo and the port of Gothenburg is the main route for Norwegian foreign trade. However, the physical infrastructure along the whole corridor has partly a limited capacity to accommodate increasing freight flows, which can weaken the fluidity of trade and ultimately worsen the competitiveness of the STRING stretch.

The OECD report further states that past trends in freight transport indicate that rail is losing competitiveness to road. Since 2009, there has been a continuous decrease in the number of freight trains crossing the Swedish-Norwegian border in Western Scandinavia. Both in Norway and Sweden, intercity railway networks focus on connecting the capital city with the rest of the country. As a result, the cross-border connection between Oslo and Gothenburg consists of long stretches of single track,

⁸ OECD (2018), OECD Territorial Reviews: The Megaregion of Western Scandinavia, OECD Territorial Reviews, OECD Publishing, Paris, <https://doi.org/10.1787/9789264290679-en>

which not only reduces the frequency but also the average speed at which trains can travel between these two metropolitan areas.

As estimated by the two national transport administrations of Norway and Sweden, freight delivery times by train along the Oslo-Gothenburg stretch are twice as long as by lorry⁹. Similarly, cars can go around 30 km/h faster than the passenger trains.

North and south of the Fehmarn Belt, rail activities are very low. As mentioned before, since 1997 no freight trains have been running at all via Fehmarn Belt, due to the fact that the ferries were then only opened to passenger trains. In 2019, the rail activities via ferries were stopped at all, due to workings for the planned Fehmarn Belt Fixed Link on the Danish side. From 2022 on, the rail activities will also be stopped on the German side between Puttgarden and Lübeck.

For the rail part we could identify the following existing and partly future bottlenecks on the corridor.

Table 15: Existing and potential future bottlenecks on the STRING stretch - Rail

	Section	Bottleneck	Classification	
NO	Network	Limited train length < 740 m	Technical	Train length
NO	Sandbukta - Moss - Såstad	Only single-track	Technical	Lanes / tracks
NO	Moss	Limited capacity in Moss	Technical	Capacity
NO	Haug – Sarpsborg – Halden – Kornsjö	Only single-track and partly steep gradients	Technical	Lanes / tracks
SE	Network	Limited train length < 740 m	Technical	Train length
SE	Kornsjö – Öxnared	Only single-track gradients, curves	Technical	Lanes / tracks Max speed
SE	Älvängen – Gothenburg, Gothenburg – Kungsbacka	Capacity issues in and around Gothenburg hub including Central station	Technical	Capacity
SE	Kungsbacka – Ängelholm	Lack of sidings	Technical	Lanes / tracks
SE	Ängelholm – Maria – Helsingborg	Only single-track	Technical	Lanes / tracks
SE	Hamra – Varberg	Single-track	Physical	Lanes / tracks
SE	Halmstadt Railway station	Limited capacity	Technical	Capacity
SE	Lund – Flackarp – Arlöv	Two-track railway, but limited capacity	Technical	Capacity
SE	Arlöv – Ängelholm	Only single-track (obstacle for new local passenger trains and growing freight trains)	Technical	Lanes / tracks

⁹ <https://www.banenor.no/globalassets/utredningen-oslo-goteborg---hovedrapport.pdf>

	Section	Bottleneck	Classification	
SE	Lockarp – Trelleborg	Only single track which limits future development of traffic	Technical	Lanes / tracks
SE / DK	Helsingør – Helsingborg (HH Tunnel)	Connection between Helsingborg in Sweden and Helsingør in Denmark via two tunnels under the Öresund	Physical	Missing link
SE / DK	Öresund bridge land connection	Not sufficient capacity on the Öresund Fixed Link land connections	Technical	Capacity
SE / DK	Öresundsmetro Malmö – Copenhagen	Not sufficient capacity on the Öresund Fixed Link after opening of the Fehmarn Belt Fixed Link	Physical	Missing link
SE / DK	Kalvebod – Peberholm	As part of Öresund Fixed Link, not sufficient rail capacity in future	Technical	Capacity
DK	Køge station, combi terminal and Ringsted junction	Only single-track at Køge station	Technical	Lanes / tracks
DK	Vordingborg - Nykobing Falster	Only single-track	Technical	Lanes / tracks
DK	Ringsted – Rødby	No electrified double-tracks	Technical	Electrification
DK	Tinglev – Padborg	Only single-track	Technical	Lanes/tracks
DK / DE	Fehmarn Belt Fixed Link	Currently only ferry link	Physical	Missing link
DE	Puttgarden – Großenbrode	Axle load < 22,5 tonnes	Technical	Weight restrictions
DE	Puttgarden-Lübeck	Not electrified Only single-track	Technical	Electrification Lanes / tracks
DE	Fehmarn Sound Bridge	Limited capacity of the existing Fehmarn Sound Bridge as hinterland connection from and to the Fehmarn Belt Fixed Link.	Technical	Capacity
DE	Bad Oldesloe – Hamburg	Limited rail track capacity between Bad Oldesloe and Hamburg	Technical	Capacity
DE	Elmshorn – Hamburg	Limited capacity between Elmshorn and Hamburg	Technical	Capacity
DE	Hamburg main and Altona station	Hamburg main station and Altona station are over 100 years old and no longer able to cope with the increasing demand and traffic	Technical	Capacity

Source: KombiConsult/Ramböll analysis; several bottlenecks are to be removed by envisaged projects, see chapter 4 and following

Road

As mentioned before, for road, significant investments already helped upgrading the road infrastructure on the STRING stretch to reach a good level, but still there are also some issues to be looked upon. For the road network we could identify the following bottlenecks on the corridor.

Table 16: Existing and potential future bottlenecks on the STRING stretch - Road

Country	Section	Bottleneck	Classification	
SE	Malmö – Helsingborg	Partially capacity, sensitive for incidents	Technical	Capacity
SE	Vellinge – Trelleborg	2-lane road through Trelleborg to port, which limits port and logistic centre development	Technical	Lanes / tracks
SE / DK	Kalvebod Bridge	Bridge with 2 x 2 lanes and annual traffic at 110,000 vehicles is over capacity	Technical	Capacity
DK	Copenhagen Eastern Ring Road	A feasibility study is finalised analysing how a ring road can relieve traffic congestion. Can possibly add more traffic to the STRING corridor and strain capacity	Physical	Missing link
DK	Fredericia – Kolding	2x2 lane motorway. Peak hour congestions. EIA for widening to 6/8 lanes has been carried out, but funding not yet provided	Technical	Capacity
DK	Odense SØ – Odense V	2x2 motorway. Peak hour congestion. EIA and Construction Act has been approved. Funding not yet provided	Technical	Capacity
DK	Odense V – Middelfart	2x2 lane motorway currently being widened to 3x3. Complete in 2022. Peak hour congestions	Technical	Capacity
DK	Little Belt	The current motorway bridge across Little Belt carries just under 90.000 vehicles per day (weekdays, 2019) and peak hour congestion is expected in near future	Technical	Capacity
DK / DE	Fehmarn Belt Fixed Link	Currently only ferry link	Physical	Missing link
DE	Puttgarden – Heiligenhafen	German Federal road B 207, no motorway and not sufficient traffic lanes between Puttgarden and Heiligenhafen	Technical	Lanes / tracks
DE	Fehmarn Sound Bridge	Limited capacity of the existing Fehmarn Sound Bridge as hinterland connection from and to the Fehmarn Belt Fixed Link.	Technical	Capacity

Country	Section	Bottleneck	Classification	
DE	Hamburg	Limited capacity at the motorway A7 as double function for commuter/local and long-distance traffic north of Hamburg	Technical	Capacity
DE	Hamburg	Permitted traffic intensity of motorway A7 south of Elbe Tunnel is exceeded by 31%	Technical	Capacity
DE	Hamburg	The motorway A1 between the triangle-junction Hamburg-Southeast and Hamburg-Harburg is already highly frequented and much more traffic is forecasted	Technical	Capacity
DE	Hamburg	Prolongation of motorway A26 to connect A7 and A1 needed to improve connectivity of port, relieve inner city traffic	Physical	Missing link
DE	Hamburg	Koehlbrandbrücke, an important connection to the port, is old cannot longer cope with the increasing heavy weight traffic	Technical	Capacity

Source: KombiConsult/Ramböll analysis

Intermodal terminals, marshalling yards

For the intermodal terminals and marshalling yards, we could identify the following bottlenecks on the corridor.

Table 17: Existing and potential future bottlenecks on the STRING stretch – RRT/marshalling yard

Country	Section	Bottleneck	Classification	
SE	Malmö Kombiterminal	Full capacity	Technical	Capacity
SE	Marshalling yards in region Skåne (Malmö and Helsingborg)	Full capacity	Technical	Capacity
DE	Lübeck Skandinavienkai	Full capacity	Technical	Capacity

Source: KombiConsult/Ramböll analysis

Ports

Gothenburg, Malmö and Trelleborg have generally excellent ports and port terminals. Accessibility to the ports is very good for Gothenburg and Malmö. For Trelleborg, the accessibility would need to be improved. The Copenhagen part of the Copenhagen Malmö Port has no rail access but it has been assessed as economically not justifiable to build a rail connection to the terminals. This is due to the fact that they are operated by joint company and a division of labour – the Malmö port handles goods transport whereas the Copenhagen port mainly handles cruise ships.

Rail border crossings

Capacity issues especially in rail transport remain a major challenge that causes instability of operations and delays. In addition, different standards between countries make cross-border operation and implementation of cross-border services harder. The Scan-Med RFC (Rail Freight Corridor), a cooperation between the Infrastructure Managers on the longest Rail Freight Corridor in Europe, has set up three working groups. In the regional working group “North” it was mutually agreed to follow “operational interoperability” issues in detail, such as:

- Different language requirements on the route;
- Capacity expressed in “PaP” (Pre-arranged Paths) is fine, but “ad hoc” slots are required during the year, and more flexible reaction to offer them;
- Construction works and contingency planning of RFC Scan-Med should also take into account the potential of ferry services;
- Long-term need for additional fixed links in Greater Copenhagen Area under study, such as the Öresundmetro or HH tunnel;
- ERTMS, in particular ETCS existing working groups, financial schemes and idea to establish similar for the DK/DE border at Padborg (Jutland route) and Fehmarn (Fehmarn Belt Fixed Link);
- Longer and heavier trains (“740m”), including potential extension of 830m also for the Swedish connections east and north of Malmö (Gothenburg/Hallsberg);
- Structure Gauge / Intermodal Loading Gauge allowing for the transport of 4 m high semi-trailers as a permanent classification of the infrastructure rather than by daily approvals.

The following figures shows an overview of challenges the railway undertakings have to deal with on cross border sections.

Figure 5: Overview of rail parameters on Rail border crossing “northern borders”

	DE (DB Netz)	DK (Banedanmark)	SE (Trafikverket)
Border station		Padborg CPH	Malmö
Handover		Padborg	Peberholm
Electric Supply	15kV~; 16.7 Hz	25kV~; 50 Hz	15 kV~; 16 2/3 Hz
Train Control	PZB	ATZ (ETCS ~ 2023)	ATC2*
Train length [m]	740 -> 835 (Maschen-Padb.)	835	≈ 630 (740 planned)
Brake position	„Lange Lok“ (P) + G	Lange Lok“ (P) + G	G -> R
Wagon List format	DB Netz	Banedanmark	Trafikverket
Tail signal	Plate	Plate (change only for Alborg)	Plate
Language	DE	DK	SE
Other		Unusual transport database Wagon list to DK recipient Delayed trains get new N°	* From 1.01.2019 vehicles must have ERTMS Baseline 3 on board in addition to ATC2 devices, and a Specific Transmission Module (STM) transferring ATC2 track side messages to vehicle ERTMS' unit

Source: Banedanmark, KombiConsult analysis, 8/2017

4 The Measures and Projects Eliminating Bottlenecks

To cope with the identified bottlenecks, several measures are planned or are in the realisation phase with the purpose of impact in terms of capacity relief on the STRING stretch, improving connectivity for a joint labour market, or moving goods from road to rail. The tables in Annex show an overview of those measures on the STRING stretch.

These include 38 rail and 19 particular road projects with the two Multimodal projects Fehmarn Belt Fixed Link and Fehmarn Sound bridge counted twice since they support both road and rail. The rail investments account for € 36,1 bn, with the highest share in Norway with € 13,2 bn, followed by Denmark with € 9,5 bn (including Fehmarn Belt Fixed Link as cross-border project, but financed by the Danish side), Sweden (€ 9,3 bn), and Germany (€ 4,1 bn). Particular road investments of € 13,3 bn are planned in Denmark with highest share with € 10,5 bn, followed by Germany with about € 2,8 bn, Sweden with € 20 m, and cross-border projects between Sweden and Denmark with € 10 m.

In the following, the measures are described in more detail.

Norway

The Norwegian section of the stretch has four main investments planned by the Norwegian Railway Directorate, which are fully financed by the government. These are in particular (heading southwards):

- **Follobanen:** a new double-track railway from Oslo S to Ski, designed for the speed up to 250km/h running parallel to the existing railway line (Østfoldbane). The project includes 22 km of new railway, of which 19,5 km will be in a tunnel. Construction work started in 2013 and the railway should be opened for traffic in December 2022. This project is part of the InterCity global investment where a significant number of Norwegian cities will be connected with Oslo as a main hub. It should result in an increased capacity (from twelve to forty trains per hour), reduce travel time by 11 minutes (half of today's travel time) and decrease the risk of delays. This line is originally planned with implementation of "Class B" signalling system (ATC system, but not fully upgraded in compliance with ERTMS specifications). The "National plan for railway signals" states that there is high probability that this system will be upgraded to ERTMS. This decision has not yet been made and that entails some uncertainty concerning the budget and railway signalling system.
- **Sandbukta – Moss – Sâstad:** This section is about the construction of 10 km of a double-track railway from Sandbukta to Sâstad, including reconstruction of the Moss railway station. Construction work started in 2019 and should be finished by 2024. This line is also originally planned with implementation of "Class B" signalling system (ATC system, but not fully upgraded in compliance with ERTMS specifications). The "National plan for railway signals" states that there is high probability that this system will be upgraded to ERTMS. This decision has not yet been made and that entails some uncertainty concerning the budget and railway signalling system. The new Sandbukta-Moss-Sâstad rail link will make life a lot easier for Oslo's commuters in the future, together with other InterCity projects. This ensures that the travel time between Oslo and Fredrikstad will be just 47 minutes, an improvement of 21 minutes. It's an environmentally friendly solution that enables much higher passenger volumes in and out of Oslo.
- **Haug (Råde) – Halden:** Construction of 57 km of a double-track railway between Haug (Råde) and Halden, with capacity improvements in 4 railway stations. Construction works should be finished for Råde - Fredrikstad by 2029, Fredrikstad - Sarpsborg by 2032 and Sarpsborg - Halden

by 2034 – as part of the global InterCity project¹⁰. This project has identified some serious geotechnical challenges which most probably will have a negative impact on total cost and/or completion year.

- **ERTMS implementation:** It is planned that the route between Oslo and S-Halden on the Swedish border will be equipped with ERTMS in phases from 2023 to 2030. Some parts of this plan will be realized through projects which includes complete construction or reconstruction of the railway lines mentioned above. But this plan is still in an early phase and there is no specific data for this corridor. Currently envisaged project end date: 2034!

Sweden

Also, in Sweden the implementation of projects is progressing, but there are also huge delays. Most projects are financed within the national plan for infrastructure investments. The current plan for infrastructure investments 2018 - 2029 states investments and financing of infrastructure during a 12-year period. The plan is revised every fourth year. Swedish transport administration (Trafikverket) has started the preparation for the next coming plan that will cover the period 2022 – 2033 or 2037. The government has instructed Trafikverket to investigate measures specifically targeted to achieve a CO2-neutral transport system by year 2045. Furthermore 205 billion SEK should be reserved for high-speed railways 250 km/hour or higher speed. In spring 2021, the parliament will decide over the infrastructure proposition with specific directions for the next infrastructure plan. The proposition contains budget frames and particular investments that must be included in the next plan. At the end of 2021 the parliament will determine the next plan.

Apart from investments financed within the national plan it also specifies urgent investments that has not been possible to be financed in the current plan. Among these investments we find Oslo – Gothenburg (capacity issues and long travel times), capacity deficits in the regional system for public transport (rail and road) in greater Gothenburg area, the HH tunnel project.

Studies on the new high-speed rail lines – outside the STRING stretch – Ostlänken, Gothenburg-Borås and Lund – Hässleholm have started. However, financing and standard of the entire high-speed rail line between Stockholm – Jönköping – Gothenburg/Malmö is still not decided.

On the Swedish side, the Swedish Transport Administration has the following main financed investments:

- **ERTMS:** Current railway does not comply with TEN-T Regulation regarding ERTMS. According to plan ERTMS is to be implemented by 2030.
- **Train length:** The national railway system, according to the current railway network statement, is designed for 630-meter-long freight trains. Upgrades to support 740-meter-long freight trains are made continuously. However, the main bottlenecks for operating 740-meter-long trains are at marshalling yards and terminals which in general does not have sufficient lengths of tracks for building longer trains without extra shunting. Malmö marshalling yard has strategic importance as main railway node for cross-border freight trains. Thus, measures for longer trains, in particular 740-meter trains, are planned. Sidings will be built by 2029.
- **Skålebol – Öxnared:** This section is a single-track stretch of importance for passenger trains Oslo – Gothenburg and Gothenburg – Karlstad. It is also an important stretch for freight transport from northern Sweden to ports of Gothenburg. A study for choosing the right measures is ongoing.

¹⁰ <https://www.banenor.no/Prosjekter/prosjekter/intercity/>

- **Flackarp – Arlöv – Lund:** Arlöv – Lund is a two-track railway that is of strategic importance to develop railway traffic in southern Sweden. Works for capacity increase to four tracks are ongoing and will be finished by 2023.
- **Olskroken (Gothenburg):** Reconstruction of the track system in Olskroken, including grade separation, will increase accessibility in the Gothenburg area. Project to be completed by 2026.
- **Älvängen station:** A minor investment in an additional track at the Älvängen station to increase service capacity on the Norge-Vänerbanan railway line. The project is set to be completed by 2026.
- **Gothenburg – Älvängen:** This section is fully used with extensive regional trains as well as long distance trains. The stretch is also important for freight transport to/from Port of Gothenburg. Measures are planned in Älvängen to increase efficiency for passenger trains.
- **Gothenburg port line:** the Gothenburg port line will be upgraded to double track, including a new bridge. The investment will increase capacity in one of the busiest freight railways in Sweden and is estimated to be completed by 2023.
- **Western Swedish Rail package (Västsvenska paketet järnväg):** To cope with the growing demands of the regional population in western Sweden, the Western Swedish package aims to contribute to positive and sustainable growth in the Western part of Sweden. It includes several measures in the railway system in the Gothenburg area, such as the construction of the West Link, also known as **Västlänken**, which is an eight km long double-track city tunnel. It will also add three new stations at Haga, Korsvägen and Gothenburg central. The railway in central Gothenburg is used to its full capacity. Gothenburg central station is an end station for passenger trains. The project is set to be completed by 2026. With the tunnel, train frequencies can be increased, travel times will be reduced, and passengers can reach more destinations without transfers.
- **Gothenburg – Kungsbacka.** Current capacity does not allow for increased passenger trains due to growing demand.
- **Varberg double track:** Construction of just over five km new double track between Varberg and Hamra until 2024, of which approximately will be three km in tunnel. A new travel centre with station will also be constructed.
- **Gothenburg – Ängelholm:** Lack of sidings limits the capacity for freight trains.
- **Ängelholm – Maria – Helsingborg:** This part is a one-track stretch. Investments for double-track is financed within current plan. The stretch is for passenger trains only. Part Ängelholm – Maria shall be completed until end of 2023, for Maria – Helsingborg part the completion is unknown.
- **Ängelholm – Kävlinge – Arlöv:** Part of TEN-T Core network, this railway section is single-track, dedicated to freight trains. Works that aims to develop local passenger trains are ongoing.
- **Marshalling yards and terminals:** Major marshalling yards and terminals are located in Malmö, Helsingborg and Gothenburg. Malmö marshalling yard is fully used and train operators also use the marshalling yard in Helsingborg, though it is not an ideal solution. Efficiency measures are taken in Malmö but the challenge is that expansion is not possible. Region Skåne has studied possible solutions for a new marshalling yard. The study concludes a localisation at Marieholm along the Malmö – Ängelholm stretch, but there are no political decisions promoting a particular solution.

Sweden / Denmark

It should herewith be stressed that the expected growth after Fehmarn Belt Fixed Link is operational will lead to future capacity deficits between Sweden and Denmark. Regions/municipalities have

studied different options. The Greater Copenhagen Traffic Charter (regional/local) promotes the “HH Tunnel” (linking Helsingør – Helsingborg) and the Öresund Metro (a new link as a complement to the existing Öresund fixed link), in that order. There has been agreed that a fixed link between Elsinore and Helsingborg must be built first and commenced so quickly as possible, as well as that the Öresund Metro is connected to the expansion of Copenhagen metro, but can be built independently of whether one HH connection has been decided. On state level, Sweden and Denmark are studying the alternative of a HH fixed connection (ongoing).

- **Öresund Bridge land connection:** In the “Greater Copenhagen Traffic Charter”, realized by the project “A Coherent Transport System in Greater Copenhagen” and agreed between the Capital Region of Copenhagen and the Skåne Region, it is stated as a priority that “Bottleneck issues at the Öresund Bridge should be solved, e.g. at the stations at Ørestad and at the airport, plus capacity enhancements at both sides of Øresund”. The project concludes that the land connection should be enhanced on both sides of the bridge in order to maximise the use of the rail capacity of the bridge itself (which is not the bottleneck). It is expected to be on the upcoming national investment plan in 2020/2021. On the Swedish side until Svågertorp station there are four tracks, the old railway around Malmö and the city tunnel, where freight and passenger traffic meet, and two tracks from Svågertorp to the bridge. On the Danish side there are approx. 10 km shared tracks, including sharing with the internal Danish rail traffic to the airport. This section is owned by Øresund Bridge Consortium
- **HH Tunnel:** The HH Tunnel is a project which shall connect Helsingborg in Sweden and Helsingør in Denmark via two tunnels under the Öresund. According to current studies there shall be a railway tunnel for passenger traffic (9 km long) and a tunnel for road traffic (14 km long). For the railway tunnel there will be an extended station in Helsingborg and a new station in Helsingør. The road tunnel will also be connected with the E6 on the Swedish site, and on the Danish site with the motorway at Helsingør. The tunnels shall be re-financed by user fees within 24 years after opening. The financing itself shall be done via so-called Sund og Bælt Model, a State Guarantee Model, like it was used for the Öresund bridge, or via PPP. Costs are estimated at about € 3,3 bn (34 bn DKK). In 2018 a new pre-study was started by the two national authorities. The directives for this pre-study does not contain any freight train adaptation for the tunnel. This study shall be finished by the end of 2020. When being built, it is expected that the tunnel may be opened in 2035.
- **Öresund Metro:** The Öresund Metro is a project studying a Metro link between Malmö and Copenhagen, connected to existing and planned infrastructure/public transport. Forecasts show that freight and passenger train traffic between Scandinavia and Central Europe will increase when the Fehmarn Belt Fixed Link is completed. Freight traffic crossing the Öresund Bridge are expected to almost double in numbers of trains. This will put pressure on the existing rail capacity and may worsen the already low reliability on traffic across the Öresund Fixed Link and its hinterlands. A driverless high-speed metro line between Copenhagen and Malmö - the Öresund Metro – will improve both the connectivity for people and businesses in the cross-border region as well as relieving capacity on the Öresund Fixed Link to enable expansion of freight and long-distance passenger traffic on the TEN-T corridor, and subsequently on the STRING stretch. The Öresund Metro will reduce travel times between Malmö and Copenhagen to a travel time of about 20 minutes with departures every 1,5 minute, increasing the number of people who can reach each other across the Öresund within one hour from 1,3 million to 2,3 million. Phase IV of the preliminary study shall end in March

2021 (prolonged due to Covid19). Preliminary study phase IV contains communication activities and analysis of international, regional and local benefits of an Öresund Metro.

Denmark

- **Ringsted – Odense:** upgrade of the existing rail line between Ringsted and Odense to 200 km/h. the upgrading is expected to be finished in 2022.
- **Odense – Kauslunde (Middelfart, Vestfyn Line):** Construction of a new 35 km high speed railway line (250 km/h) across Western Funen. The new line for long-distance passenger traffic will remove a current bottleneck, will resolve capacity problems, and reduce risk of delays. Following the construction of the new railway line, the existing line will benefit from increased capacity for the continued use of freight transport and local passenger trains. Status: The EIA was concluded in 2016. The project is part of the decision by the Danish government, "Investeringsplan 2030" (Transport Master Plan 2030). The parties involved agreed to set aside DKK 4,848 million. (2019-pl) to a new high-speed line between Odense V and Kauslunde. The project will be launched in 2024 and completed in 2029. Danish Road Directorate, in continuation of the preparation of the EIA report for the project, will be responsible for the construction of the project with Banedanmark as supplier of the railway technical elements.
- **Ringsted – Fehmarn (Rødby):** The section Ringsted-Fehmarn is part of the Fehmarn Belt project. Rail Net Denmark is responsible for carrying out the upgrade of the existing - about 115 km - Danish railway line between Ringsted and Fehmarn Belt. This includes the electrification of the line, upgrading the infrastructure to enable increased speed of up to 200 km/h, as well as establishing double tracks across the islands of Lolland and Falster. In addition, passing tracks for 1.000 m long freight trains will be established along the line. It is expected to serve 20 passenger train services each day, compared to six passenger trains currently. Current status: Upgrade of the line across Zealand and the island of Falster will be completed by 2021, while electrification of the line will be finished in 2024. The work on the island of Lolland will be coordinated with the time plan for the tunnel work to be carried out across the Fehmarn Belt.
- **New Storstrøm Bridge:** The Storstrøm Bridge as part of the STRING stretch is also part of the Fehmarn Belt railway network. The new double track 4 km railway bridge will replace the single-track bridge built in 1937. The construction of the new bridge in combination with a new high-speed railway line (200 km/h) will reduce travel time insignificantly. The increased capacity and speed will remove a bottleneck on the STRING stretch and provide a new rail freight route. In 2015, the Danish Parliament passed the Construction Act for the new bridge.
- **Double track between Tinglev and Padborg:** The main line from Vamdrup (south of Kolding) towards Padborg, at the border between Denmark and Germany, has gradually been double tracked and speed upgraded over the past 25 years. The section from Vojens to Tinglev was completed in 1996, the section from Vamdrup to Vojens was completed in 2015. The only remaining section not double tracked, is the 14 km long section from Tinglev to Padborg at the Danish-German border, though construction Act for entire section Vamdrup-Padborg was approved in 1993. An updated EIA analysis for the section Tinglev-Padborg is required.

Denmark/Germany

- **Fehmarn Belt Fixed Link:** The Fehmarn Belt Fixed Link realises a fixed, close, and direct connection between Scandinavia and continental Europe. The duration of a train journey between Copenhagen and Hamburg will be cut short from about four and a half to less than three hours. Passenger trains shall be able to drive through the tunnel at up to 200 km per

hour and freight trains at 140. In the future, freight trains will be able to avoid the 160 km longer detour via the Great Belt. This will create a strong transport corridor between Germany, Denmark and Sweden, increase mobility and result in better conditions for travelling, commuting and trade. After completion, about 118 trains per day will be expected. Depending on the scenario of German permitting process the end date may vary. German approval was given; however, the Approval was appealed at the federal court in Leipzig in 2020 which started the case in September 2020. On 3rd November 2020, the court dismissed all lawsuits so that the tunnel can be built.¹¹ In April 2020 it was already announced that the start of works for the Fehmarn Belt Fixed Link on the Danish side would start on January 2021 with an expected opening mid of 2029.

Germany

For Germany, most of the railway bottlenecks concern the hinterland connection from and to the planned Fehmarn Belt Fixed Link, where measures are planned but mainly have not started, yet, though it is fixed in the State Treaty that the hinterland connection shall be completed as close as possible jointly with the opening of the fixed link. In the Hamburg area there are several infrastructure measures that have already started to remove some bottlenecks due to limited capacity on several sections.

- **Puttgarden – Lübeck - Hamburg:** As part of the Fehmarn Belt Fixed Link hinterland connection, there will be new construction and an upgrade of the single-track section between Puttgarden and Lübeck to electrified double-tracks with complementing measures: Speed shall be increased to Vmax 160 km/h, and passing tracks shall be extended to 850m (whole section Puttgarden – Hamburg). In combination with the Fehmarn Belt Fixed Link, travel time will then be reduced between Copenhagen and Hamburg to 2,5 hours, so regions of Eastern Holstein and Lolland-Falster will grow closer together. Travel time on the section between Burg (Fehmarn) and Lübeck will be reduced by 40 minutes from 1,5 hour to only about 50 minutes.
- **Fehmarn Sound Bridge:** When the Fehmarn Belt Fixed Link will be opened, the current Fehmarn Sound bridge will not cope with the increased traffic any longer. This was already communicated in 2012. Eventually, in March 2020, it was finally decided to build a new connection between the German mainland and the Fehmarn island in form of an immersed tunnel with a double-track for rail (and four road lanes). The opening of the planned tunnel shall be 2028, still. Interestingly, after the inauguration of the Fehmarn Belt Fixed Link and until the planned Fehmarn Sound tunnel is finished, there are plans of Deutsche Bahn to electrify the current Fehmarn Sound bridge as intermediate solution.
- **Bad Oldesloe – Hamburg (S4):** On one of the most used rail sections from and to Hamburg there is limited capacity. The goal is to provide better access of rural area and hinterland of Hamburg, but also to relieve hinterland connection from and to Hamburg and Hamburg main station, avoiding mixed traffic of local, long-distance traffic and freight, and improve punctuality, travel time and reliability. Therefore, there will be dedicated railway tracks between Hamburg and Ahrensburg for the light rail S4, and the existing line will be updated on 36 km by elimination of level crossings, noise reduction measures, adding additional stations. The project shall be finished at the end of 2027.

¹¹Bundesverwaltungsgericht, Press Release N° 62/2020 of 03.11.2020. However, for the 4-lane-expansion of the federal road B207, there are still cases at local courts.

- **Elmshorn – Hamburg:** Several measures to increase the limited seating capacity for commuter and regional traffic between Elmshorn and Hamburg. Implementation of a new line S4 West with partly separate tracks to relieve also long-distance tracks.
- **Hamburg Altona station:** Due to old infrastructure (tracks and building) in Hamburg Altona station as a terminus, the Hamburg Altona station shall be relocated north to the current station Diebsteich. With this solution, several problems will be solved: a through station reduces travel time, local and long-distance traffic will be unbundled and emissions will be reduced by avoiding empty runs. Originally, the relocation should have been done until end of 2023. Due to lawsuits against the project in April 2020, the relocation now shall be finished until end of 2027.

Road

Norway

The road from Oslo to the Swedish border is a four lane Highway with a good standard, although with speed limits varying from 80 km/h on a small stretch to 100-110 km/h at the better part. Congestion into Oslo in the morning and outbound in the afternoon is a daily challenge. Cross border north bound freight traffic creates regular queues on the Swedish side of and on the Svinesund bridge due to limited Toll declaration capacity. Specially Sunday afternoons creates queuing risks with high numbers of freight vehicles combined with commuter and leisure traffic north bound from Swedish west coast and direction Oslo area.

Sweden

- The road from Norwegian border to Öresund bridge and Trelleborg has good standard with 4-lane motorway. Nevertheless, the E6 motorway passes Gothenburg in a fairly central area and is thus congested due to commuter traffic at rush hour. If more traffic is filled into the system there will be a need to create more capacity or look into other means like intelligent road pricing systems. The West Swedish road package (financed within national plan), where works have started, shall relieve the E6 from road congestion.
- The E6 between Helsingborg and Vellinge is sensitive for traffic incidents. Even minor incidents can lead to congestion. A choice of measure-study has been made and concluded that capacity increase to six lanes need to be done at least partially. For larger parts of the stretch, it is sufficient to implement limitations for heavy trucks to bypass another truck on the stretch. This measure has recently already been implemented with a successful result.

Denmark

- **Kalvebod Bridge:** Bridge with 2 x 2 lanes and annual traffic at 110,000 vehicles is over capacity
- **Copenhagen Eastern Ring Road:** A feasibility study is finalised analysing how this ring road can relieve traffic congestion. Can possibly add more traffic to the STRING corridor and strain capacity. The analysis show that it will positively impact on the congestion situation in the city centre as well as in the surrounding ring roads around Copenhagen - Ring 3 and Ring 4.
- **Odense SØ – Odense V:** Widening from 2 x 2 to 3 x 3 lanes. EIA and Construction Act has been completed. Only funding is still pending before construction.
- **Odense V – Middelfart:** Extension from 4 to 6 lanes has been carried out over the past 7 years. Two sections, Middelfart-Nørre Aaby and Aarup-Odense V has been completed. Only the last section between Aarup and Odense V is still in construction, and will be completed in 2022

- **The Road Bridge across Little Belt:** The current motorway bridge across Little Belt carries just under 90.000 vehicles per day (weekdays, 2019) and peak hour congestion is expected in near future. Several options have been studied by The Road Directorate, and an additional parallel bridge is the preferred option when the need will arise.
- **Fredericia-Kolding:** Widening from 4/6 lanes to 6/8 lanes. EIA for widening of the 6 km long section around Kolding where E20 and E45 is running jointly has been carried out, and Construction Act and funding is outstanding. The motorway currently carries 80.000 - 100.000 vehicles per day on 2 x 2 lanes sections
- **New Mid-Jutland Motorway Haderslev-Hobro:** The Motorway, for which EIA for the southern section has been completed, will relieve E20/E45 around Kolding when completed. Construction Act and funding is pending.

Germany

- **Puttgarden – Heiligenhafen:** The German Federal road B 207 shall be upgraded to a four-lane motorway. In 2015, the first planning decision was released in 2017. Due to lawsuits the planning was revised. The updated planning was published in 2017 and the planning decision was released in 2018. Currently, there are four open lawsuits and thus the planning decision is not in force, yet. The financing of estimated € 109 million is secured by the State, and works, likewise the Fehmarn Belt Fixed Link, shall be finished end of 2028.
- **Fehmarn Sound Bridge** When the Fehmarn Belt Fixed Link will be opened, the current Fehmarn Sound bridge will not cope with the increased traffic. This was already communicated in 2012. Eventually, in March 2020, it was finally decided to build a new connection between the German mainland and the Fehmarn island in form of an immersed tunnel with four road lanes (and a double-track for rail). The opening of the planned tunnel shall be 2028, still.
- **Hamburg A7 (north of the river Elbe):** The motorway A7 between Bordesholm and north of Hamburg, which is a highly frequented section, was already extended from four to six lanes recently. The section of the motorway A7 between the federal state border Schleswig-Holstein/Hamburg and mid of Hamburg (Elbtunnel) is even more highly frequented with about 154.000 cars per day, due to the double function for local and run-through traffic, which shall increase furthermore in the future. Besides the lane extension from six to eight lanes in order to increase the capacity on that section, there are also measures to reduce noise emissions in form of high noise barriers and three tunnels in the Hamburg area. There are three part of which the first part was finished in 2019 and the last part is planned to be finished until end of 2028.
- **Hamburg A7 (south of the river Elbe):** South of the Elbe Tunnel, on a stretch of 4.2 kilometres, the motorway A7 will be extended from six to eight lanes as the permitted traffic intensity is exceeded by 31%.
- **Hamburg A1:** On the motorway A1, on a stretch of 8.2 kilometres between the triangle-junction Hamburg-Southeast and Hamburg–Harburg, the motorway will be extended from six to eight lanes until 2030. Now, this section is highly frequented with about 131.000 cars per day (24% of the traffic is heavy-duty-traffic). Until 2030, 160.000 cars per day with a share of 27% for heavy-duty-traffic are forecasted.
- **Hamburg A26 (east):** On a stretch of 9.2 kilometres the motorway A26 will be prolonged connecting the motorway A7 and A1. This route shall be an efficient east-west connection which also improves the accessibility of the port of Hamburg.

- **Hamburg Koehlbrand Bridge:** The Koehlbrand bridge which is an important connection to the port of Hamburg and also partly connecting A7 and A1 shall be replaced by a tunnel. The bridge is highly frequented with 32.000 cars per day.

Ports

Sweden

- **Trelleborg:** The port of Trelleborg is undergoing a modernization with new births to handle larger RoPax vessels and restructuring of the physical design of the port area and a truck centre in the vicinity of the port, a few kilometres northeast. In the eastern part of the port new space is created for the departure/arrival of trucks and railway waggons. The overall project also includes construction of a new ring road to access the port parallel to the current rail access. Among the RoPax services are railway ferries between Trelleborg and Rostock.

5 Recommendations / critical issues / what still needs to be done

5.1 Impact of envisaged projects / measures

The successful implementation of the before mentioned measures and projects on the route from Oslo to Hamburg will contribute to overcome a majority of the identified bottlenecks and missing links. They address a great variety of critical issues, such as future requirements on technical parameters, existing or future capacity constraints on routes or within urban nodes, or missing links, and will lead to sufficient capacity, reduction of greenhouse emissions, reduced travel times, and more flexibility and reliability of transport services on the STRING stretch.

When all the envisaged measures for rail would be implemented, for instance, this can lead to a reduction of the travel time via Fehmarn by over four hours on the whole route, leading to an estimated travel time of just 9 hours from Oslo to Hamburg, hypothetically speaking. Even more important is the reduction of the travel time for the individual sections such as Oslo – Gothenborg (ca. 3 hours) or Copenhagen – Hamburg (ca. 2,5 hours) and thus below the “4 hours” threshold and thereby allowing a day trip. With these measures, and the possibility for trains to run non-stop via the Fehmarn Belt Fixed Link in a high frequency, the quality level for passengers will be improved significantly and makes it more comfortable to travel by rail.

Figure 6: Travel times for rail 2020 and after implementation of envisaged measures via Fehmarn

Section	2020	2020-2030	2030		
	Travel time hh:mm	Reduction hh:mm	Travel time hh:mm	Distance km	Speed km/h
Oslo					
Gothenborg	03:30	00:32	02:58	342	115
Malmö	03:05	00:00	03:05	300	97
Copenhagen	00:50	00:30	00:20	40	120
Rødby	02:50	02:00	00:50	170	204
Puttgarden	00:45	00:38	00:07	19	163
Hamburg	02:40	01:00	01:40	157	94
Total / Ø	13:40	04:40	09:00	1.028	114

Source: KombiConsult/Ramböll analysis

Early forecasts by Femern A/S expect that 74 freight trains per day are using the Fixed Link in 2035. Kombiverkehr states that for every truckload on average about 60 g of greenhouse gas emissions will be reduced per tonne-kilometre by shifting from road to rail. If we assume only one intermodal service with two departures per day in each direction with an average of 40 intermodal loading units between Oslo and Hamburg, over 61.000 tonnes of CO2 equivalents per year would be saved by shifting from road to rail on that route.

Table 18: CO₂-savings for intermodal rail/road connection Oslo - Hamburg

CO ₂ savings per tkm (g)*	Trains per day both directions	Trains per year both directions	loading units per train	loading units per year	loading weight per unit (t)	shifted tonnes per year	shifted tkm per year for 1.028 km	CO ₂ savings per year (t)
(g)	(trains)	(trains)	(LU)	(LU)	(t)	(t)	(tkm)	(t)
60	4	1.000	40	40.000	25	1.000.000	1.028.000.000	61.680

Source: KombiConsult/Ramböll analysis

As concerns the route via Jutland, there are also significant improvements to be expected. The section between Copenhagen and Fredericia is part of the so-called “The hour Model”, which shall bring down the travel time between the four largest cities of Denmark to one hour by building new or upgrading existing lines to high-speed lines. But the hour model has not been approved yet as the national infrastructure plan is not agreed upon yet. Negotiations are expected to take place sometime in Jan/Feb 2021. Until then it is not clear if the hour model will be a part of the future national plan. The hour model can also be seen in the light of current analysis of a Kattegat-link which is a direct connection between Copenhagen and south of Aarhus via Kattegat. If the parliament agrees on this project, there will be much less need for the hour model if any. However, if the hour model would be applied, this will reduce the travel time for the whole route between Oslo and Hamburg by one and a half hour down to just more than 11 hours. We assume that the reduction for the overall travel time will be higher as not all envisaged projects could be quantified at the moment due to their different maturity.

Table 19: Travel times for rail 2020 and after implementation of envisaged measures via Jutland

Section	2020	2020-2030	2030		
	Travel time hh:mm	Reduction hh:mm	Travel time hh:mm	Distance km	Speed km/h
Oslo					
Gothenborg	03:30	00:32	02:58	342	115
Malmö	03:05	00:00	03:05	300	97
Copenhagen	00:50	00:30	00:20	40	120
Odense	01:26	00:26	01:00	170	170
Kolding	00:44	00:00	00:44	70	95
Padborg	00:51	00:00	00:51	100	118
Hamburg	02:14	00:00	02:14	178	80
Total / Ø	12:40	01:28	11:12	1.200	107

Source: KombiConsult/Ramböll analysis

This would support the implementation of long-distance passenger rail services, including night trains, as it is foreseen in the German “Deutschlandtakt” systems that will be enlarged to cross border services which are connected to regional and local services in the nodes. It would also match with the plans to establish a new “TransEuropExpress (TEE) 2.0” systems of well interconnected high-speed rail services in Europe which was presented by the German presidency of the Union on the occasion of the rail freight summit in Berlin on 21.09.2020.¹²

Outlook on compliance with TEN-T Regulation requirements by 2030

After analysing the envisaged projects that are KPI-relevant and have a completion date before 2030 the following main developments for rail are expected by 2030:

- **Electrification:** The remaining gaps of electrification in Denmark and Germany will be closed by ongoing or planned projects.
- **N° of tracks:** STRING’s standpoint is that an improvement of the existing railway stretch between Oslo – Gothenburg to double track and deployment of potential for high-speed rail services is essential to overcome the prospective challenges for traffic in the entire corridor. Together with actions to attract more rail freight between Norway and Sweden, the double track investment is necessary to create jobs, sustain economic growth and improve the quality of environment in the STRING geography - as pushing for new rail solutions is deemed the only sustainable alternative for medium to long travels. Projects are running or planned to achieve double-tracks on the STRING stretch in three of the four countries, in particular Norway, Denmark and Germany until 2030. Though, in Norway some parts are planned, they are expected only to be finished until 2034, or on some other parts (i.e. Halden – Kornsjö) there are still no plans when or how this shall be upgraded to double-tracks. Between Haug and Halden there have been identified some geotechnical challenges which most probably will have a negative impact on total cos and/or completion year. In Sweden, there are no concrete plans for double track for the missing link Öxnared – Kornsjö. In this period Trafikverket are studying the short stretch Öxnared – Skälebol but no investment decisions are taken yet as described further down in the document. In Denmark, an updated EIA analysis for the remaining single-track section Tinglev-Padborg is required.
- **Line speed:** 100 km/h line speed for freight will not be achieved, though the remaining non-compliance sections are quite short. Remaining speed limitations are to be expected in Norway (section Vestby – Kambo, about 15 km) and on two smaller urban sections in Germany between Danish-German border and Hamburg.
- **Axle load:** Concerning permitted axle load, remaining limitations in Germany shall be closed in the framework of the upgrading of the hinterland connection of the planned Fehmarn Belt Fixed Link by 2029.
- **Train length:** Progress is expected regarding the permitted train length up to 740 m. In Sweden, in particular, projects are ongoing to achieve compliance. Germany has also set up dedicated programmes to further improve the situation regarding the parameters “Train length” above the required 740 m up to 835 m in conjunction with the Fehmarn Belt Fixed Link hinterland connection. In Sweden rail is challenged by longer road trains and it even more crucial to go for longer trains in order to support the modal shift goals.

¹² <https://www.bmvi.de/SharedDocs/DE/Video/Youtube/innovativer-schienengueterverkehr-21-09-2020.html>

- **ERTMS:** ERTMS deployment is agreed upon only until 2023. The 2030 values are set as targets only with no commitment on underlying projects so that in particular full ETCS deployment can be doubted, if no acceleration is agreed upon. Nevertheless, the two railway administrations of Norway and Sweden gradually implement ERTMS installations along the Oslo S-Ski-Halden-NO/SE border-Gothenburg line by 2030. Some parts of this plan will be realised through construction or reconstruction projects, such as the one on the Råde – Halden section. Denmark has ambitious plans to equip the entire Danish railway network with ERTMS and has recently opened the first line. The implementation of ERTMS in Denmark on the Scandinavian Mediterranean Corridor, and thus on the STRING stretch, is scheduled to be in operation until mid of 2029. Thus, in principle ERTMS will be implemented, but most probably after 2030 in terms of the whole STRING stretch.

As a result of the envisaged projects above, the following table compares the expected compliance in 2030 of the STRING rail stretch with the requirements according to the TEN-T Regulation.

Table 20: Expected compliance of the STRING stretch with TEN-T rail requirements in 2030

	Track gauge	Traction	N° of tracks	Line speed	Axle load	Train length **	ERTMS In operation	
Targets \ Country	1,435 m	All lines electrified	double track	≥ 100 km/h	≥ 22,5 t	≥ 740 m	ETCS	GSM-R
NO	100%	100%	65%	66%	100%	0% - 100%	65%	100%
SE	100%	100%	67%	100%	100%	64% - 100%	100%	100%
DK	100%	100%	97%	100%	100%	100%	100%	100%
DE	100%	100%	100%	96%	100%	100%	30%	100%
Total*	100%	100%	83%	95%	99%	100%	82%	100%

* Due to different length (weighting) of the sections, the total percentage is not the average of the individual country figures; ** As the incompliance was mainly a result of the changes of the network statements before, the expected status may vary from X% to 100% in Norway and Sweden

Source: KombiConsult/Ramböll analysis

Roads

High quality roads are indispensable for maintaining speed and safety standards, and to mitigate critical issues on the Corridor's road network. To avoid congestion in and around large cities or in geographically limiting areas, bottlenecks and missing links need to be addressed. Sweden is committed to a "Vision Zero", meaning to significantly reduce the number of fatalities in road transport. Among other things (promotion campaign, raise sensitivity, implementation of ITS) the reduction of level crossings at roads will be important infrastructure measures to achieve this.

Clean fuels

Electricity and electric vehicles have been promoted very strongly in whole Europe and all STRING stretch countries have their own strategies to increase the share of electric vehicles and number of charging stations. All countries have tax incentives for electric vehicles and e.g. Germany and Sweden are giving grants for the purchase of electric vehicles. Besides tax incentives and purchasing grants, Norway has e.g. allowed electric vehicles to park and charge freely and even use the bus lanes. Due to strong promotion, Norway has more electric vehicles per capita than any other country in Europe. Denmark's target is to be independent of fossil fuels by 2050 with three official policy papers for the development of alternative fuels. The Bilkommission ("Car Commission") is expected to publish their final report in the first quarter of 2021 with recommendations for Denmark how to enhance a green transition from fossil mobility to fossil-free mobility. The first part of the recommendations has been published and a political agreement has been made. The target is 775.000 low emissions cars before 2030, but no reductions in fossil cars before 2030. Though the charging station network is already relatively comprehensive on the whole STRING stretch, there are still several plans to construct new stations, which is indeed needed to attract more people to shift to clean fuels. As concerns other technologies for providing cars with electricity, there are also certain measures to provide e.g. cars and trucks with electricity directly on roads, such as in Sweden and Germany. One of the electric highways in Germany that is currently tested is in particular on the STRING stretch: 10 km with overhead lines on both sides on the A1 motorway near Lübeck. Too, other alternative fuels such as CNG, LNG and H2 are developed further in the STRING countries, albeit to different degrees.

Rail/Road Terminals

In addition to the three terminals already fulfilling the requirement for 740 m trains, Hamburg Billwerder is subject to capacity and layout upgrade measures and with that, already committed to achieving compliance with the parameter (≥ 740 m train length) by 2030. For the other terminals, there are project ideas but "works are not yet planned/agreed for realisation", so that only slight improvement is expected compared to the current situation. It is recommended that rail infrastructure managers and terminal managers cooperate in a coordinated way to achieve the track- and terminal-side improvement and harmonisation of that parameter which will bring an efficiency increase to (intermodal) rail transport.

5.2 What needs to be done in addition

Despite the above, corridor evolution is hampered, as various rail projects may face delays or financing uncertainty, though there are only a few projects which are expected to be concluded only after 2030 or have no exact finalisation date at all, or financing is not totally approved yet. This insecurity regarding on-time completion applies – among others - to some key rail projects with vital importance for the corridor, such as the Fehmarn Belt Fixed Link that achieved planning permit also on the German side in January 2018, which however was recently a case at the Federal Administrative Court in Leipzig. The court then decided on 3 November 2020 and dismissed all lawsuits. Nevertheless, the southern access route to the Fehmarn Belt Fixed Link is still in the planning phase (Germany) and it is uncertain if it will also be finalised until 2029.

Norway

740 m trains development is a future target. However, there are a number of hurdles in the Norwegian railway infrastructure to be solved before it can be completed including reconstruction of the Alnabru terminal. Hence focus on double tracks and elimination of sections with strong inclination are recommended as the prime focus at the Norwegian side of the border.

There are thus three important focus areas that can enhance railway capacity on the Norwegian part of the STRING corridor:

- Continuous focus on converting existing single-track lines north of Halden to double track in line with the planned InterCity railway development. Completing double track to Halden by 2034 is most important. At present financing of the southernmost stretch is unsure. Geotechnical issues north of Sarpsborg is another uncertainty.
- As soon as possible start planning of the Halden – Kornsjö stretch for double-track alignment including bypassing the existing 25‰ inclination in Tistedalen.
- Cross border cooperation between the Norwegian Railway Directorate and the Swedish counterpart Trafikverket with the aim of initiating planning processes including financing of double-track railway from Kornsjö to Öxsnered. Alternatively, construction of a sufficient number of double-track sections to enhance capacity significantly.

Sweden

- Infrastructure measures in current national plan will give possibilities to develop passenger trains more in compliance with travel demand. The regions Västra Götaland and Skåne both have ambitious plans to develop local and regional train traffic that exceeds infrastructure capacity even after implementation of the national plan for investments in infrastructure.
- Investment in double-track for section Skånebol – Öxnered, which is not included in current investment plan, would make it possible to develop train traffic from Gothenburg northwards. In the national forecast Oslo – Gothenburg is assumed to be used by one train per hour. One train every two hours offers services with few stops while one train can be characterised as regional train with more stops between endpoints. The bottleneck that prohibits a more intense traffic is the stretch Älvängen – Gothenburg, which is fully used even after implementation of the national plan. Without capacity increase at this stretch there is no need for capacity increases between Skånebol and Kornsjö. It would, however, be beneficial to invest in measures to increase design speed Kornsjö – Ed and Bäckebo – Dals Rostock which as today varies from 60 to 159 km/hours (type A-trains). At the border crossing at Kornsjö the maximum speed for type A-trains is below 60 km/hour.
- With renewal of the fleet for regional trains crossing Öresund the passenger capacity will increase. With developed services for regional and long-distance passenger trains, as well as expected increase of freight trains due to Fehmarn Belt Fixed Link the land links of the Öresund bridge on either side can be expected to be fully used around 2030 – 2035. Capacity at marshalling yards in Sweden might limit the number of freight trains crossing the DK/DE border.
- Studies on the new high-speed rail lines – outside of the STRING stretch – Ostlänken, Gothenburg – Borås and Lund – Hässleholm have started. However, financing and standard of the entire high-speed rail line between Stockholm – Jönköping – Gothenburg/Malmö is still not decided. From the viewpoint of STRING lower travel time – e.g. by higher speeds – for the Malmö – Gothenburg section would be beneficial.

Sweden / Denmark

The Greater Copenhagen Traffic Charter¹³ suggests that future cross border capacity increase should be solved by (in this priority):

- (1) a fixed link for passenger trains and road vehicles between Helsingborg and Helsingør (HH project), and
- (2) extension of Copenhagen Metro to Malmö ("Öresund Metro").

Additionally, the charter concludes that the land connection should be enhanced on both side of the Öresund bridge (at Ørestad and at the Copenhagen airport, plus capacity enhancements at both sides of Øresund e.g. in the stations) in order to maximise the use of rail capacity of the bridge itself. In the Greater Copenhagen Traffic Charter it is stated as a priority that "bottleneck issues at the Oresund Bridge should be solved, e.g. at the stations at Ørestad and at the airport, plus capacity enhancements at both sides of Øresund".

On the section between Malmö and Trelleborg, the consultants see two critical issues, one for rail and one for road. As concerns rail, the longest part with about 27 km between Lockarp (south of Malmö) and Trelleborg is still single-track. This limits the future development of traffic, but currently no measures are planned at all. For road, between Vellinge and Trelleborg it is only a two-lane road through Trelleborg to the port, which also limits the port and logistic centre development. Meanwhile the municipality is working to solve the issue although National Transport Administration is not willing to invest here.

Denmark

In Denmark the critical need and focus is on upgrading the rail network (capacity, electrification and signals), and on completing the land connections to the Fehmarn Belt Fixed Link. Current status is that the upgrade of the line across Zealand and the island of Falster will be completed by 2021, while electrification of the line will be finished in 2024. The work on the island of Lolland will be coordinated with the time plan for the tunnel work to be carried out across the Fehmarn Belt. After the positive outcome of the German plan approval process the end date may be fix with 2029. Another priority should be the upgrading of the remaining single-track section between Tinglev and Padborg to double-track.

Denmark / Germany

The current status of the planning documents of the Fehmarn Belt Fixed Link have to be improved due to recently discovered reefs, which were missing in the construction application. Their protection was not foreseen in the building permit of Federal State of Schleswig-Holstein for the German part and therefore Schleswig-Holstein requires some corrections in the construction application and the start of the project could be delayed. Currently the start of works was announced for January 2021 with an expected opening mid of 2029, which is already later than initially planned (end of 2028). Additionally, though German approval was given; the approval was appealed at the Federal Administrative Court in Leipzig which has started the court hearing as of 22.09.2020. Eventually, on 3 November 2020 the court dismissed all lawsuits against the project. The planning must "only" be enhanced with the protected riffs. Thus, no further delays are expected from this side.

¹³ Agreed within the Greater Copenhagen partnership among the Capital Region of Copenhagen and the Skåne Region, and others, including Eastern Denmark and South Sweden

Germany

One uncertainty on the German side are the costs for the Fehmarn Belt Fixed Link Hinterland connection on German territory that were initially estimated between € 1.5 bn and € 1.7 bn. Recently, in 2019, the Bundesrechnungshof (Federal Court of Auditors) assumed that the costs may increase up to € 3.5 bn, which would be more than twice than the preceding estimation. German railways (Deutsche Bahn), on the other hand, estimates costs of about € 2.8 bn, which is lower than the Bundesrechnungshof estimated, but still much higher than initially assumed. One of the main reasons for the increase in costs is that a large part of the line is being rebuilt along a different route due to citizen participation. In addition, the German Bundestag decided to also finance supra-legal measures for noise protection along the route. In addition to that, the cost estimations for the Fehmarn Sound crossing, which is now planned as an immersed tunnel, have doubled from € 350 million up to € 700 million. As concerns the timeframe, the construction works for the Fehmarn Belt Hinterland connection on German territory shall begin at 2021/2022, and shall be finished in the timeframe of the Fehmarn Belt Fixed Link, end of 2028. Nevertheless, due to contract the double-track only have to be finished seven years after Fehmarn Belt Fixed Link opening. Thus, the finalisation of the construction works within the timeframe of the Fehmarn Belt Fixed Link opening can be seen as a remaining risk, as it is not contractually secured.

6 Summary

In the framework of the present study bottlenecks and missing links hampering the further development of in particular rail transport for passengers and freight in the STRING stretch of the TEN-T Corridor Scan-Med between Oslo and Hamburg have been analysed. A “missing link” is literally a missing piece of infrastructure. The Fehmarn Belt Fixed Link is the prominent example where, according to the plan approval, its completion including the hinterland connections in Denmark and Germany would be able to modally shift volume to rail significantly and contribute to a regional integration like the Øresund bridge demonstrated it since its completion. As a consequence of its positive impact, stakeholders in the Øresund region have put forward the concept of further fixed links between Sweden and Denmark, namely the “HH project” which is made of a road and a rail connection between Helsingborg and Helsingør and the “Øresund Metro” which would be a dedicated regional rail passenger line between Copenhagen and Malmö, both also aimed at relieving capacity constraints on the Øresund bridge.

Priorities from the corridor perspective via Fehmarn route:

Fehmarn Belt Fixed Link: As mentioned, a “missing link” is literally a missing piece of infrastructure. Thus, building the Fehmarn Belt Fixed Link itself is absolutely necessary in order to make the route via Fehmarn work at all. As the building of the Fehmarn Belt Fixed Link is generally secured, even more after the positive decision of the Bundesverwaltungsgericht in Leipzig in November 2020, focus should hereby lie on keeping the deadline for its realisation, which is currently **2029**.

Surrounding measures: To make the whole corridor via Fehmarn route work efficiently and not having the Fehmarn Belt Fixed Link as an “isolated solution” after it has been realised, there are “surrounding” infrastructure measures which are essential and need to be done simultaneously. Focus should hereby lie on keeping the same deadline until **2029** for the finalisation of the projects as for the Fehmarn Belt Fixed Link. These are in particular already planned measures for a continuous electrification on the whole route from Oslo to Hamburg and the elimination of the remaining single-track sections, in order to allow the trains to run through without any waiting times for oncoming trains and increase the capacity by allowing a two-way traffic in both directions.

- **Eliminating non-electrified sections:** Northern and southern access to the Fixed Fehmarn Belt Link in Denmark and Germany at Ringsted – Rodby, Puttgarden – Lübeck
- **Eliminating single-track sections:** Northern and southern access to the Fixed Fehmarn Belt Link in Denmark at Vordingborg - Nykøbing F and Germany at Puttgarden – Bad Schwartau, and at further sections in Norway: Sandbukta – Moss – Sastad, Haug – Sarpsborg – Halden (currently only until 2034 for the last section!), and Sweden: Ängelholm – Maria – Helsingborg

Priorities from the corridor perspective via Jutland route:

As the corridor is already quite well developed, focus should hereby lie on the development of the high-speed railway line between Ringsted and Kauslunde, which will help reducing the travel time significantly and relieve capacity issues on the high frequented sections between Copenhagen and

Kauslunde. As the first upgrade between Ringsted and Odense is expected to be finished already in 2022, focus hereby should lie on the section between Odense and Kauslunde, which shall only start in 2023 and be finished in 2029. Initially the project was intended for completion by 2014!

For road, completion of the outstanding widening projects Odense SØ-Odense V and around Kolding on the E20 along the Jutland route.

Priorities from the corridor perspective via Fehmarn & Jutland route:

Comprehensive measures: Improving cross border services, regional or local/commuter passenger services, interconnected with urban mobility, in nodes or sections with current or expected future capacity limitations (e.g. after the Fehmarn Belt Fixed Link is in full operation) can help also relieving capacity issues for long-distance traffic. Thus, those are measures that needs to be done in order to benefit the most by envisaged travel time reductions, higher train frequencies, etc.

- High speed measures such as Follobanen between Oslo and Ski
- Further measures for relieving (current, future) capacity bottlenecks such as
 - Flackarp-Alröv-Lund (updgrade to four tracks)
 - Gothenburg – Älvängen
 - Several measure in Gothenburg area / Western Swedish Rail package
 - Land connections to the the Øresund bridge on both sides
 - Missing fixed links between Sweden and Denmark (Øresund Metro, HH Tunnel)
 - New Storström bridge
 - Fehmarn Sound bridge replacement
 - Bad Oldesloe - Hamburg

Priorities from the corridor perspective from and to Trelleborg:

Extension of single-track sections to double-track between Lockarp and Trelleborg and increasing capacity of the two lane-road at Trelleborg to the port for a better future development of the port of Trelleborg.

Priorities from the non-compliance infrastructure perspective

Number of tracks: Double track rail lines are essential to allow higher speed, higher frequencies and increase the resilience in case of disturbances in comparison with single-track sections. Therefore, additionally to the beforementioned projects including upgrading single-track sections to double tracks, focus should lie on the remaining single-track sections¹⁴ without current plans for elimination:

- Norway: Halden – Kornsjø, and
- Sweden: Kornsjø – Öxnared, Maria – Helsingborg, Ängelholm – Arlov via Åstorp, Lockarp – Trelleborg
- Tinglev-Padborg

¹⁴ Denmark: Tinglev – Padborg: although “only” a single-track section of around 11 km, this has been assessed as non-critical by Danish authorities, infrastructure managers and rail (freight) service providers

Train length: It should be priority for Sweden and Norway to focus on achieving a general compliance up to 740 m train length to be allowed on the rail network. Second priority should be to achieve a harmonisation between all the countries on the corridor for the same train length. Otherwise, a higher train length e.g. in Denmark than in the other countries cannot be fully utilised. This includes the Rail-Road terminals with handling tracks making it possible to accept 740 m trains (Høje Taastrup, Helsingborg, Halmstadt, Arken and Alnabru) and electrification of rail access in even more sites.

ERTMS: Though an ERTMS deployment is planned in all four countries, their maturity and planning status is quite different. Literally, the European Deployment Plan includes no progress by 2023, and consequently all measures are delayed after that date. Therefore, priority should hereby lie on two things: Definition of particular projects for installation of ERTMS on the corridor other than those single sections which are integrated in other projects as mentioned before, and a better harmonisation in terms of timing between the different countries in order to ensure that trains can run-through the whole stretch using ERTMS relatively at the same time and thus allowing higher frequencies, making journeys safer, etc., for all sections and not as isolated solutions.

Clean fuels: All STRING countries have their own strategy and already provide a comprehensive network of charging stations. Besides alternative fuels such as CNG and LNG, further promoting zero emission techniques such as electricity and electric vehicles in a more harmonized way by all STRING stretch countries is strongly advised to e.g. increase the share of electric vehicles and number of charging stations not only at or near urban nodes, but also for enabling long distance traffic on the whole route.

Transport Master Plans: Update national Transport Master Plans to make sure that existing projects/measures are maintained and new projects are integrated with high priority and that their financing is secured from National Budget, Resilience and Recovery Facility (RRF) and Connecting Europe Facility (CEF II), as well as innovative financial instruments (user fees, loans, state guarantees, ...). Also, a better harmonization between the different national Transport Master Plans is needed.

Annex I Identified Projects/Measures on the STRING stretch - Rail

	TEN-T ID	Section	Project name / short description	Project Promoter	Project end date	Budget (Mill. €)	Funding source incl. potential	Approval Status
NO	5185	Oslo – Ski	Follobanen, new double track	Norwegian Railway Directorate	12/2022	2.800	State budget	Approved
NO	5650	Ski – Halden	Implementation of ERTMS system	Norwegian Railway Directorate	12/2034	3.050	State budget	Potential
NO	5183	Sandbukta - Moss - Såstad	Extension to double-track railway and reconstruction Moss railway station	Norwegian Railway Directorate	12/2024	1.050	State budget	Approved
NO	5182	Haug(Råde) – Sarpsborg – Halden	Double-track railway, capacity improvements in 4 railway stations	Norwegian Railway Directorate	12/2029 12/2034	6.300	State budget	Potential
SE	5656	Trollhättan-Göteborg	Norge-Vänerbanan, additional track at Älvängen	Swedish Transport Administration	12/2026	15	State budget	Approved
SE	5159	Göteborg	West Sweden railway package	Swedish Transport Administration	12/2026	2.598	State budget Region/municipality CEF	Approved
SE	5161	Göteborg	Reconstruction of the track system in Olskroken including grade separation	Swedish Transport Administration	12/2026	268	State budget Region/municipality	Approved
SE	5162	Göteborg	Upgrade to double track on the port line and the Marieholm bridge	Swedish Transport Administration	12/2023	376	State budget Region/ municipality CEF	Approved

	TEN-T ID	Section	Project name / short description	Project Promoter	Project end date	Budget (Mill. €)	Funding source incl. potential	Approval Status
SE	5163	Varberg	Upgrade to double track	Swedish Transport Administration	12/2024	519	State budget Regions, Municipalities	Approved
SE	5646	Halmstad C/bangård	Upgrade of the Halmstad node for increased capacity and safety	Swedish Transport Administration	12/2026	36	State budget Regions, Municipalities	Approved
SE	5165	Ängelholm – Helsingborg	Upgrade to double track and grade-separated crossings. Reconstruction of Maria station.	Swedish Transport Administration	12/2023	259	State budget Regions, Municipalities	Approved
SE	5653	Maria - Helsingborg C	Upgrade to double track	Swedish Transport Administration	Unknown	392,81	State budget Regions, Municipalities	Approved
SE	-	Helsingborg – Helsingør	HH Tunnel. Two tunnels under the Öresund, one for passenger railway traffic (9 km) and one for road traffic (14 km)	Swedish and Danish Transport Administration	12/2035	3.300	State budget	-
SE	5169	Åstorp – Teckomatorp	Expansion of sidings, increased line speed, introduction of modern signalling systems and new stations for passenger services.	Swedish Transport Administration	12/2022	66	State budget Municipalities	Approved
SE	5167	Lund (Högevall)-Flackarp	Expansion from two to four tracks between Flackarp and Högevall. New signals along the route and new station for commuter trains to be built at Klostergården.	Swedish Transport Administration	12/2023	120	State budget	Approved
SE	5401	Kävlinge – Arlöv	Capacity enhancements and new stations for passenger service	Swedish Transport Administration	12/2022	30	State budget Municipalities	Approved

	TEN-T ID	Section	Project name / short description	Project Promoter	Project end date	Budget (Mill. €)	Funding source incl. potential	Approval Status
SE	5657	Kävlinge – Arlöv	Etapp 2 (Malmöpendeln Lommabanan). New sidings on single track for increased capacity	Swedish Transport Administration	12/2026	21,66	State budget Regions, Municipalities	Approved
SE	5166	Flackarp – Arlöv	Two new tracks on between Flackarp-Arlöv, ~75% of the route Lund-Arlöv	Swedish Transport Administration	12/2023	444	State budget Regions, Municipalities CEF/TEN-T	Approved
SE	-	Trelleborg/Malmö - Kornsjö (Oslo)/Hallsberg/Stockholm	Measures for longer trains (750 meter)	Swedish Transport Administration	12/2029	175	State budget	Approved
SE	5153	Stockholm (Älvsjö) - Malmö/(DK) Border	ERTMS ScanMed East Etapp 1	Swedish Transport Administration	12/2029	642	State budget	Approved
SE	5559	Kontinentalbanan Malmö.	Upgrade noise reduction measures. Upgrade for passenger traffic.	Swedish Transport Administration	12/2020	52	State budget Region	Approved
SE / DK	5998	The Öresund Metro Phase 4	Preliminary study phase 4 contains communication activities and analysis of international, regional and local benefits of an Öresund Metro	City of Malmö and City of Copenhagen	09/2020	0,6	City of Malmö, City of Copenhagen ERDF	Approved
SE / DK	-	Peberholm – Kalvebod	Upgrade of Kastrup Station due to the limited capacity, which only is expected to get worse	-	12/2025	-	-	-
DK		Kalvebod Bridge	Analysis on-going, but in very early stages	-	-	-	-	-

TEN-T ID		Section	Project name / short description	Project Promoter	Project end date	Budget (Mill. €)	Funding source incl. potential	Approval Status
DK		Køge station, combi terminal and Ringsted junction	Development of double tracks at Køge station, increasing capacity at Køge combi terminal. Improvement of the Ringsted junction	-	12/2028	-	-	-
DK	5395	Ringsted – Odense	Speed increase to up to 200 km/h. Various upgrades in Ringsted, Sorø, Slagelse, and at the Great Belt Bridge etc. [pending political decision on preferred technical solution]	Rail Net Denmark	12/2023	65,10	State budget	Approved
DK	5396	Odense – Kauslunde	The construction of a new 35 km high speed railway line (250 km/h) across Western Funen	The Danish Road Directorate	12/2023	624	State budget	Approved
DK	5135	New Storstrøm Bridge	New double track 4 km railway bridge	The Danish Road Directorate	12/2022	493,14	State Budget CEF/TEN-T	Approved
DK	-	Tinglev – Padborg	Development of double tracks	-	-	-	-	-
DK	5134	Ringsted – Rødby	Development of electrified double tracks	Rail Net Denmark	12/2028	1.275	Tolls and railway charges CEF	Approved
DK / DE	5390	Fehmarn Belt	Fehmarn Belt Fixed Link with an electrified double track	Femern A/S	12/2028	7.060	State budget CEF/TEN-T	Approved
DE	5000	Puttgarden - Lübeck	Development of electrified double-tracks	BMVI (DB Netz)	12/2028	1.518	State budget CEF/TEN-T	Approved
DE	5096	Fehmarn sound	New bridge/tunnel (southern access to Fehmarn Belt Fixed Link)	BMVI (SH)	12/2028	700	State budget	Not all approved
DE	5077	Bad Oldesloe – Hamburg	Upgrade of railway tracks (S4)	Federal states of Hamburg, Schleswig-	12/2027/2028	1.847	State budget Federal states of Hamburg,	Approved

	TEN-T ID	Section	Project name / short description	Project Promoter	Project end date	Budget (Mill. €)	Funding source incl. potential	Approval Status
				Holstein (DB Netz)			Schleswig-Holstein (DB Netz) CEF/TEN-T	
DE	5764 5472	Elmshorn – Hamburg	Upgrade of railway tracks (S4 and S4 West) and stations	Federal states of Hamburg, Schleswig-Holstein (DB Netz)			State budget CEF/TEN-T	Approved
DE	-	Hamburg central station	Hamburg main station - building of five new access stairs to the platforms	DB Station und Service	12/2023	-	-	-
DE	-	Hamburg central station	Hamburg main station - extension of station hall	DB Station und Service	12/2030	-	-	-
DE	-	Hamburg Altona	Relocation of Hamburg Altona to new station Diesteich Hamburg Altona station	Land Hamburg	12/2027		DB Netz	-

Source: KombiConsult/Ramböll analysis; Fehmarn Belt Fixed link and Fehmarn Sound included in Rail and Road list due to their nature of a multimodal infrastructures.

Annex II: Identified Projects/Measures on the STRING stretch - Road

	TEN-T ID	Section	Project name / short description	Project Promoter	Project end date	Budget (Mill. €)	Funding source (incl. potential)	Approval Status
SE	5452	8 stations	Nordic Hydrogen Corridor: zero emission transport between the capitals of the Nordic countries with fuel cell vehicles	Vätgas Sverige Ideell Förening (Hydrogen Sweden Association) (Sweden)	12/2022	19,37	CEF/TEN-T Private	Approved
SE/DK	5698	Several stations	High speed electric mobility across Europe	CLEVER A/S (Denmark)	12/2022	9,69	CEF/TEN-T Private	Approved
DK	5498	Copenhagen	H2Bus Europe	Everfuel A/S (Denmark)	12/2023	39,63	CEF/TEN-T Private	Approved
DK	-	Kalvebod Bridge	Bridge with 2 x 2 lanes and annual traffic at 110,000 vehicles is over capacity	-	-	-	-	-
DK	-	Copenhagen Eastern Ring Road	A feasibility study is finalised analysing how this ring road can relieve traffic congestion. Can possibly add more traffic to the STRING corridor and strain capacity	Municipality of Copenhagen	203?	3.000	Land value capture	Not Approved
DK	-	Odense SØ – Odense V	Widening from 2 x 2 to 3 x 3 lanes. EIA and Construction Act has been completed. Only funding is still pending before construction.	The Danish Road Directorate	-	-	-	-
DK	-	Road Bridge across Little Belt	Peak hour congestion over the current motorway bridge across Little Belt is expected in near future. Several options have been studied, and an additional parallel bridge is the	The Danish Road Directorate	-	-	-	-

TEN-T ID		Section	Project name / short description	Project Promoter	Project end date	Budget (Mill. €)	Funding source (incl. potential)	Approval Status
			preferred option when the need will arise.					
DK	-	Fredericia – Kolding	Widening from 4/6 lanes to 6/8 lanes. EIA for widening of the 6 km long section around Kolding where E20 and E45 is running jointly has been carried out. Construction Act and funding is outstanding.	The Danish Road Directorate	-	-	-	-
DK	-	Haderslev-Hobro	New Mid-Jutland Motorway. EIA for the southern section has been completed, will relieve E20/E45 around Kolding when completed. Construction Act and funding is pending.	The Danish Road Directorate	-	-	-	-
DK	5393	Odense West – Middelfart	Extension from 4 to 6 lanes	The Danish Road Directorate	12/2022	365,00	State budget	Approved
DK	5394	Jutland Fredericia – Kolding	Extension from 4 to 6 lanes on a section of 19 km. The EIA was concluded in 2011, but no construction works so far and funding is not yet secured either	The Danish Road Directorate	-	80,53	-	Not secured
DK/DE	5390	Fehmarn Belt	Fehmarn Belt Fixed Link with four lanes	Femern A/S	12/2028	7.060	State budget CEF/TEN-T	Approved
DE	5096	Fehmarn Sound	New bridge/tunnel (southern access to Fehmarn Belt Fixed Link)	BMVI (SH)	12/2028	700	State budget	Partly approved
DE	5010-	Puttgarden – Heiligenhafen	Extension of lanes to four lanes	BMVI (SH)	12/2022	249,4	State budget	Approved

	TEN-T ID	Section	Project name / short description	Project Promoter	Project end date	Budget (Mill. €)	Funding source (incl. potential)	Approval Status
DE	5018, 5019	Hamburg	A 7 motorway: upgrade to 6-8 lanes between Hamburg/Schleswig-Holstein border and Hamburg/NW (A 23) / Othmarschen	BMVI (HH)	12/2028, 12/2020	26,6, 307,55	State budget	Approved
DE	5026	Hamburg	A7: South of the Elbe Tunnel, on a stretch of 4.2 kilometres, the motorway A7 will be extended from six to eight lanes	BMVI (HH)	12/2023	240,00	State budget	Approved
DE	5021	Hamburg	A1: On a stretch of 8.2 kilometres between the triangle-junction Hamburg-Southeast and Hamburg-Harburg, the motorway will be extended from six to eight lanes until 2030.	BMVI (HH)	12/2030	295,40	State budget	Approved
DE	5719	Hamburg	A26 (east): On a stretch of 9.2 kilometres the motorway will be prolonged connecting the motorway A7 and A1. This route shall be an efficient east-west connection which also improves the accessibility of the port of Hamburg.	BMVI (HH)	12/2025	942,00	State budget	Approved
DE	-	Hamburg	Koehlbrand Bridge: As an important connection to the port of Hamburg and also partly connecting A7 and A1 shall be replaced by a tunnel.	BMVI (HH), BVMi (Bund)	-	-	-	-

Source: KombiConsult/Ramböll analysis; Fehmarn Belt Fixed link and Fehmarn Sound included in Rail and Road list due to their nature of a multimodal infrastructures.

Annex II: Identified Projects/Measures on the STRING stretch - Maritime

	TEN-T ID	Section	Project name / short description	Project Promoter	Project end date	Budget (Mill. €)	Funding source (incl. potential)	Approval Status
SE	5547	Trelleborg	Long-term achievements (LARS): Construction of a new berth № 13 and quay № 14, Land filling works Removal of a current port bottleneck with a road crossing solution	Trelleborgs Hamn AB (Sweden)	12/2021	43,9	Private CEF/TEN-T	Approved
SE	5571	Trelleborg	Studies for the development and relocation within and towards the port of Trelleborg, with a view of alleviating the existing congestion through the city centre.	Zarząd Morskich Portów Szczecin i Świnoujście S.A. (Poland)	12/2021	4,9	Private CEF/TEN-T	Approved

Source: KombiConsult/Ramböll analysis