Scandinavian links

Mega bridges/tunnels linking the scandinavian peninsula to the european continent

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SCANDINAVIAN LINKS: MEGA BRIDGES/TUNNELS LINKING THE SCANDINAVIAN PENINSULA TO THE EUROPEAN CONTINENT

Christian Wichmann Matthiessen and Richard D. Knowles

Mega projects can be spectacular and of high architectural quality. Many are not. Motorways, railroads, harbours, airports, tunnels or dikes seldom present themselves as aesthetic elements of the landscape. Transmission lines, military installations, windmill parks and power plants are often considered grim and ugly, with some hydroelectric power plants as possible exceptions. Skyscrapers, monuments and religious buildings can often be of high architectural quality. But bridges are almost always of aesthetic and architectural quality. Nearly all bridges are simply beautiful; large bridges are inevitably of excellent aesthetic and architectural quality and most people consider their object of creating interaction as praiseworthy.

Until 1997, Sjælland (Zealand), with the metropolitan city of Copenhagen, the Danish capital (1.8 million inhabitants), was an island. The Danish island was connected to the European continent with very strong and efficient ferry lines. Westward to continental Denmark, large ferries carrying trains and cars departed every hour and the crossing time over the Storebælt (the Great Belt) was 1 hour (26 km between harbours for train ferries and 19 km for car ferries) plus embarkation and disembarkation time of 20 min. Eastward to Sweden from metropolitan Copenhagen to the 3rd largest Swedish city of Malmö (0.5 million inhabitants) and the 10th largest city of Helsingborg (0.1 million inhabitants), large ferries for trains and cars crossed four times per hour, ferries for cars only three times per hour, and passenger ferries and hydrofoils completed the picture with direct connections from city centre to city centre twice an hour. The large ferries crossed Øresund (Oresund or the Sound) at the shortest distance (4 km between harbours) some 45 km away from central Copenhagen and took 20 min plus embarkation, disembarkation, customs and passport clearing time of 30 min. The hydrofoils took 50 min (distance of 35 km) plus embarkation, disembarkation, customs and passport clearing time of 10 min. To the south between Denmark and Germany on the route from Copenhagen to Hamburg, large ferries for trains and cars depart two times per hour and the crossing time over the Femern Bælt (Fehmarnbelt) was 1 hour (20 km distance between harbours, or 60 km on an alternative, more easterly route) plus embarkation, disembarkation, customs and passport clearing time of 20 min. During the night, departures were fewer due to lower demand.

Ferries were bottlenecks to traffic, especially when everybody wanted to use them (e.g., Friday and Sunday evening and in the peak period for tourism). Travellers had to plan for the crossing and book passage in peak hours. The price of crossing created another bottleneck, not so much for passengers (US$3-10 per trip) as for cars (US$50 per trip).

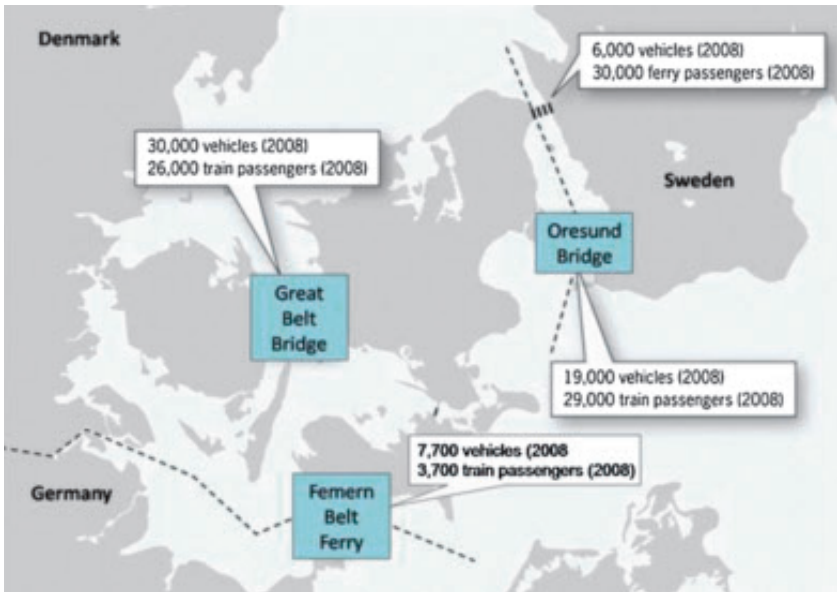

Fig. 1. The Scandinavian links.

Other barriers were especially notable when border crossing was part of the trip. Different cultures and languages – although not so much between Denmark and Sweden (Danish and Swedish languages are rather similar and cultural differences are not that great) as between Denmark and Germany – created barriers for interaction. Scandinavians understand each other's languages with little difficulty and intermarriages are as unproblematic as other marriages. Danish and German are two different languages and cultural differences are notable. Major barriers however are also deeply rooted in differences in legal systems and regulations. Thousands of paragraphs spanning from taxation through social security systems to labour market regulations presented hindrances to interaction.

The Missing Links of Europe

Transport networks remain much more extensive within than between European Union (EU) member countries despite the EU's part-funding of strategic cross-border Trans-European Transport Network (TEN-T) infrastructure. This EU investment includes motorways, high-speed trains, bridges and tunnels (Matthiessen 2004; Knowles & Matthiessen 2009; Matthiessen & Knowles 2011). The European Round Table of Industrialists set the TEN-T agenda in the late 1980s by identifying missing transport networks and links as key deficiencies and bottlenecks holding back the development of the Single Market. TEN-T aims to reorganize the dynamics between spaces, cities and regions and release the latent potential for transnational mobility. Cross-border bridges and tunnels across short sea barriers have particularly significant meaning as they allow large-scale commuting and daily interaction between locations which previously took too long to access. Many international fixed links cross river borders (such as the Rhine between France and Germany), or tunnel through mountain barriers (such as the Alps between France and Italy). On a much larger scale, the Channel Tunnel was Europe's first international fixed link to cross a major strait with its twin rail tunnels linking Great Britain and France since 1994 (Knowles 2006). Three of the 14 missing European links were located at the coasts of Zealand: (1) the Great Belt link, (2) the Oresund link, and (3) the Fehmarnbelt link (fig. 1). The first is an internal Danish link, the other two cross-national borders from Denmark to Sweden and Germany respectively. Their local settings are different. The Great Belt link is located in an average Danish setting with adjacent small cities and rural landscapes. The Oresund link is located right in the centre of the Nordic countries' largest population and economic concentration and the Fehmarnbelt is a neighbour to thinly populated peripheral regions. Two of the links are no longer missing and the third has been decided upon.

Fig. 2. The Great Belt East Bridge. (Photo: Sund & Bælt)

The National Bottleneck: The Great Belt Link

The 18 km fixed link between the Danish islands of Zealand and Funen (connected to the Jutland peninsula by bridges) across the Great Belt consists of a road suspension bridge (the East Bridge, fig. 2) and railway tunnel (the East Tunnel) between Zealand and the mid-way island of Sprogø, as well as a box girder bridge (the West Bridge) between Sprogø and Funen for motorway and railroad. The link had been discussed for more than a century and was finally decided on in 1986 and building commenced in 1988. The tunnel-bridge was opened for railroad traffic in 1997 (the reason for sending the trains through a tunnel was technical, due to weight and grade of approach ramps) and the motorway crossing the two bridges opened one year later. The West Bridge has a length of 6,611 m on 62 piers with a longest span of 110 m and a clearance below of 18 m. The East Tunnel has a total length of 8,024 m and goes down to -75 m. The East Bridge has a length of 6,790 m with a free span of 1,624 m between the two 254m high pylons and a clearance below of 65 m over the international waterway between the Atlantic Ocean and the Baltic Sea. To keep the cables in tension, anchorage structures are placed on each side of the span below the deck. Additionally, 19 pillars carry the approach deck. Construction and subsequent operation has been done by A/S Storebælt, which is a state-owned limited company. The price of bridges, tunnel and approach motorways and railroads plus interest until the opening has been US$10 billion in 2008 prices (US$8 billion, plus interest until opening for traffic of US$2.5 billion). The construction period was financed by state guaranteed loans on the international market and pay back by tolls on traffic was stipulated to take 30 years, but has been cut shorter due to underestimates of traffic. The fixed link has reduced travel time from around 90 to 10 minutes, has taken away the land-sea barrier, but kept the price barrier. The psychological effect of availability,

no queue and no pre-booking is hard to gauge. This represents a system change, which has had effects for domestic interaction where the networks were at hand in the form of family, business and public ties across Denmark. The Great Belt fixed link has changed Denmark in many ways. Logistics now operate in a single system; domestic air traffic has decreased because the fixed link offers a competitive alternative, and one-day visits have replaced overnight visits. In short, fixed links unite systems. Prior to the opening, 8,000 vehicles used the ferries every day. In 2010, the figure was 29,000.

The International Bottleneck: The Öresund

In 1992, the Danish and Swedish governments decided to build a 16 km long fixed link across Oresund (fig. 3). Construction began in 1995 and the fixed link opened for traffic in mid-2000. The decision on the investment was based on regional economic considerations although long-distance traffic was also a concern. The objective was to integrate the Malmö-Lund metropolitan region in Southern Sweden with Greater Copenhagen in East Denmark and to develop a metropolitan border region (2.5 million inhabitants) where the commercial profile could be specialized on the basis of the total volume, thus strengthening the city in the global competition. The Oresund link also related to international transport and the advantage of developing the South Scandinavian metropolis into the most important cross-point in Northern Europe, with all the associated locational advantages. In the direction Denmark-Sweden, the fixed link consists of a 4,050 m long immersed tunnel for motorway and railroad under the international waterway linking the Atlantic Ocean to the Baltic Sea, a 4,055 m long artificial island and a 7,845 m long cable-stayed bridge (upper level motorway, lower level railroad) with a free span of 490 m between the two 204 m high pylons and a clearance below of 57 m. Additionally, 51 pillars carry the approach deck. The Danish landing is directly into Copenhagen Airport, which is the most important air traffic hub in the entire Baltic Sea Region. Bridge to city distance is around 6 km on both sides. The fixed link itself draws other direct investments as, for example, it was necessary to build rail and motorway connections and therefore also to Copenhagen Airport, which became much more accessible. Construction and subsequent operation has been done by Øresundsbro Konsortiet, which is a two-state-owned limited company. The price of bridges, tunnel and approach motorways and railroads plus interest up to the opening has been US$6 billion in 2008 prices. The construction period was financed by state guaranteed loans on the international market (50% Danish guaranteed and 50% Swedish guaranteed) and pay back by tolls on traffic is stipulated to take 30 years. The integration process was slower than expected due to the national border barrier (Knowles & Matthiessen 2009; Matthiessen 2004). The networks between Danish and Swedish families and business were initially very weak, and between local governments almost nonexistent, and the toll charges presented an additional barrier. But with a certain delay of 3-5 years, inte-

Fig. 3. The Öresund Bridge. (Photo: Miklos Szabo, Øresundsbron)

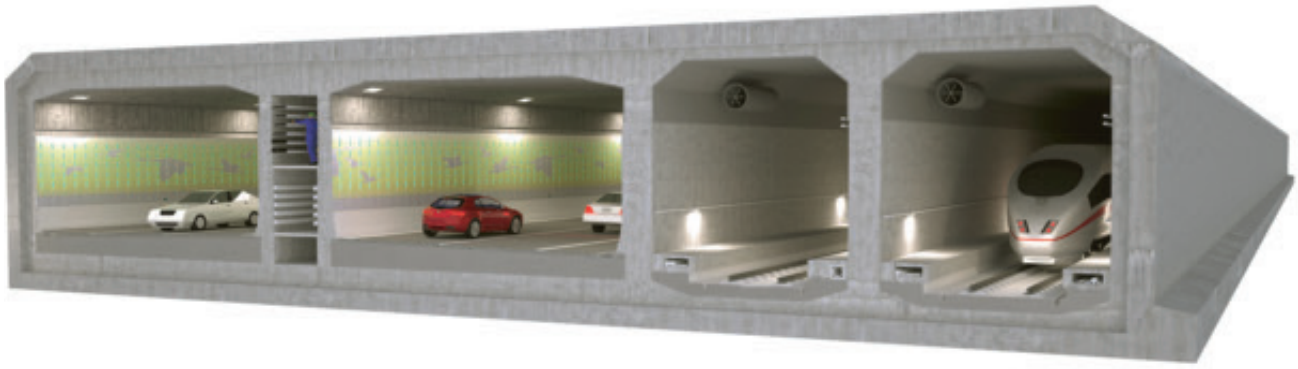

Fig. 4. The Fehmarnbelt tunnel. Proposition (Computer graphics: Femern Belt A/S)

gration developed – mostly due to price differences, but also due to real integration of markets.

The Last Missing Link: Fehmarnbelt

The most direct line between the Scandinavian Peninsula and Germany crosses the western Baltic Sea at the Fehmarnbelt. Construction of a 20 km long fixed link was finally decided upon in 2009 (fig. 4). It will provide a direct connection between Copenhagen-Malmö and Hamburg and reduce the transport time between these two metropolitan hot spots from 4.5 to 3 hours – with high-speed trains – down to less than 2 hours. With the establishment of the link across the Fehmarnbelt, we expect another type of development than the changes following the Öresund link: a link between two countries, two cultures, two languages and two administrative systems that are not closely related. There are some political, economic and cultural ties, but mobility between Germany and Denmark – and between Sweden and Germany – remains relatively low. This will change once the fixed link is completed. New opportunities will arise and new relations and new perspectives for economic growth and welfare will emerge. The labour market can develop towards much greater integration and flexibility in a cross border context. There are obvious opportunities throughout the Fehmarnbelt region to create strong groupings within a number of growth areas which are well represented in Scania, Zealand and Northern Germany: life sciences, food, IT (with the media industry as part of this), logistics, green tech, materials research and tourism. Within the scientific world, there are corresponding strengths – and complementary functions – which should be further developed. Culture can play a decisive role in an integration process. The cultural ties between the Scandinavian countries and Germany have historically been strong and German culture has impacted on large parts of European development. It is interesting however that the knowledge Danes, Germans and Swedes have about each other it rather low. Indeed, the knowledge of Danes and Swedes about Northern Germany in general and about Hamburg in particular is low. In the creation of a new regional identity, the meeting between people is one of the most important tools. Meetings between people engender follow-up activities, which ultimately mean that community investment in infrastructure is optimally utilised. The two metropolitan areas will have the possibility of daily interaction, and their crossroads location will be enforced. In the regions adjacent to the coming fixed link the development of a "real" border region is on the agenda and international traffic between the Scandinavian Peninsula and Germany will be concentrated on that corridor (Matthiessen & Worm 2011).

The Fehmarnbelt tunnel is going to be built and operated by Femern Belt A/S, which is a Danish state-owned limited company and the price is estimated at US$7 billion. On the Danish side, electrifying and rebuilding 119 km of railway from single to double track is needed and on the German side, a new bridge at Fehmarn Sound (1,000 m), 20 km of motorway and 89 km of new double track electrified railroad are needed (Matthiessen & Lundhus 2011).

Environment

Environmental considerations have been an integral part of the construction projects of the fixed links and have been of decisive significance for the choice of alignment and determination of the design of the construction. Environmental considerations were the reason the Great Belt A/S and later Øresundsbro Konsortiet established environmental monitoring programs and initiated cooperation with authorities and external consultants on the definition of environmental concerns during the construction work and the professional requirements for the monitoring program. Three environmental features were considered problematic: (1) the water balance between the Atlantic Ocean and the Baltic Sea, (2) the question of threats to nearby bird protection areas, and (3) the changes of traffic flows and the creating of economic growth due to the new effective traffic lines. First, the question of threatening water flow between the Atlantic Ocean (incoming cold saltwater) and the Baltic Sea (out-flowing warmer brackish water). The Baltic Sea receives a net surplus of water from precipitation and rivers, minus evaporation of the order of 1 m per year. This water must exit, whereas the Atlantic water does not have to flow in. The Atlantic water is very important for marine life and ecosystems in the Baltic Sea and thus for the fishing industry and tourism. It creeps in at the bottom of the Danish straits and it was feared that this "in-creeping" would be threatened by the pillars of the bridges. By a series of modelling and tests, it was shown that the major inflow of Atlantic water takes place during special high-energy storm situations, which are only active with a 5-10 years' time span. The bridges would not influence the storm situations. The potential blocking of in-creeping bottom water was still considered a problem and it was decided to comply with a zero-solution. This has been achieved by deepening parts of the Great Belt and the Oresund, so that the water flow cross-section was extended to compensate for the blocking effect caused by the bridge pylons and approach ramps. Second, the most economic building line for the Oresund Bridge cut directly through one of Scandinavia's largest bird protection areas, namely the salt marsh island of Saltholm, which is a Ramsar area (see www.ramsar.org). Thousands of waterfowls nest and many more rest there and the area has long been under natural preservation with restricted admission. To protect this island, it was decided to curve the Oresund Link so that the bridge was constructed 1 km south of the island at an extra cost of US$25 million. Third, fixed links generate increased traffic volume due to their effect on efficiency and economic growth. This in itself creates increased air pollution. The increase in pollution from new traffic is in some way compensated by significant savings in energy consumption by switching from ferries to the fixed links. Train and car ferries consume much energy for propul-

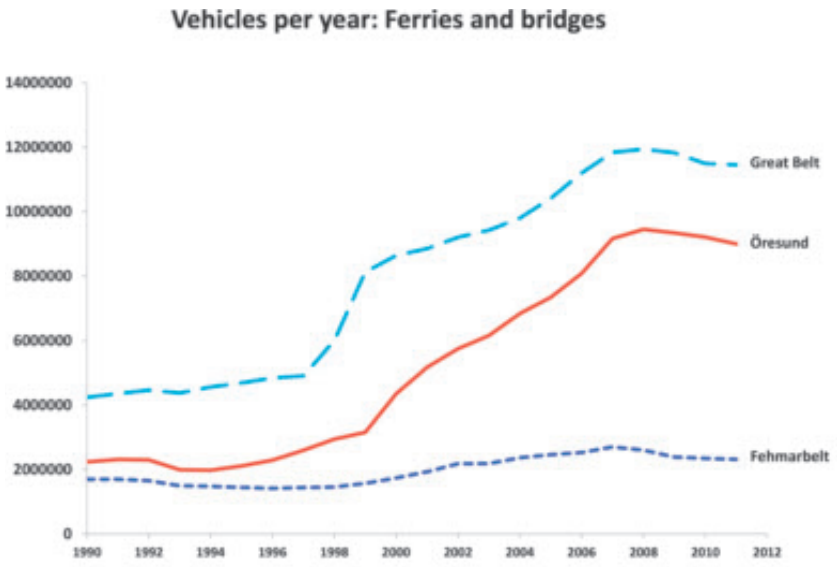

Fig. 5. Diagram showing the traffic measured by vehicles per year 1990-2011 crossing the straits around the Danish island of Zealand.

sion. High-speed ferries consume large amounts of energy at high speeds. Also, air transport is highly energy consuming. These types of traffic were expected to decrease after the opening of the bridges.

Conclusion

Ferries connect systems, whereas fixed links unite systems. The changing potential of strategically located fixed links should not be underestimated. This becomes clear when analysing the development of strait crossing traffic on the two Scandinavian links connecting the Danish island of Zealand with the European continent and the Scandinavian Peninsula with the rest of Europe. On the Danish-Danish Great Belt link, traffic increased immediately by 130% and on the Danish-Swedish Oresund link the traffic jump was a bit slower but increased by 70%. Figure 5 illustrates the changing traffic on the links. The upper curve is the Great Belt traffic on different ferry lines and since 1997-1998 on the bridge and the remaining ferry-lines. The curve demonstrates how the fixed link accelerated traffic on the Great Belt. The decrease in the middle curve on Oresund 1992-1994 is due to a fall in border retail because of the devaluation of the Swedish krone. The increase from 2000 onwards is the effect of the fixed link. The bottom curve counts ferry traffic only on the Fehmarnbelt. The Danish-Danish link profited by the fact that many networks are national and just needed the possibility of increased interaction to react. These bridges are beautiful mega engineering projects that are impressive and very visible. They are liked by most people because of that, but also due to their function, which is to connect people and economies and increase interaction. Geographers are concerned about their potential regional development impact. Forecasting this is often done by looking at their effect by taking away the land-sea bottleneck and by reducing transport time in a forecast model. But their system effect should be looked into much more by professional geographers and economists, because the dynamic effects of fixed links which take the place of ferry links can be very dramatic. Traffic on the Scandinavian links has not just presented a jump, but also an unexpected lasting new growth regime. The Scandinavian links are good examples not just of mega engineering projects but also of system effects.

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The fixed links are owned by Sund & Bælt Holding A/S, which is owned by the Danish State. A/S Storebælt (Great Belt fixed links) and Femern Bælt A/S (coming Femern Belt fixed link) are owned 100% and Øresundsbro Konsortiet (Öresund fixed link) 50% – the other 50% is owned by the Swedish State.