

Planning of large infrastructures under changing paradigms

Bridge building during the time of transition from horse to motor, 1855–1935

Jørgen Burchardt jorgen.burchardt@mail.dk
National Museum of Science and Technology, Denmark

Intro

Large infrastructure projects are responsible for the assembly of larger spaces. But planning a project is not straightforward. It is a significant decision because the infrastructure will exist for 80 years or more, and many preconditions can change within such a long time period. Infrastructures are usually very costly, and therefore it takes time to make decisions, make detailed plans, and realize a project. Over the whole period of probably more than 100 years, the transport paradigm can undergo changes.

This was the case of one of the most important bridges in Denmark, the one between Fyn and Jutland. The first rather realistic idea came up 135 years ago, and the bridge will be functioning many more years. In this period, the transport paradigm has changed several times.

The paper explains the planning processes through the actions of the different actors and spokesmen. A mix of local interests, industrial lobby, technicians, and politicians joined the political war between the established paradigm and the agents of the new era.

The first plan

A bridge over the Little Belt waters would connect two important parts of Denmark, and one could travel between Jutland and Funen without having to sail.

A connection was first mentioned in 1855 in the Danish parliament, but it would take 80 years before the bridge could finally be inaugurated. This paper is about the changing conditions of this bridge over many decades. In fact, the



A. F. Tscherning painted in 1851 four years before he proposed a connection between the two important parts of Denmark, Fyn and Jylland

many years between the bridge's proposition and implementation meant that the original plans and ideas changed in many areas. Transportation changed paradigm; where the original bridge would have been a pure railroad bridge, it ended with not only having rail but also vehicular and pedestrian road traffic.

The paradigm was changed not only for the traffic. An important change occurred in the military field, as will be explained in more detail, which was central to whether the bridge would be built at all. There were also some changes in the technique of building bridges that provided new opportunities. An additional aspect was one of social issues, wherein new taxes made funding possible.

Let's start chronologically. The spokesman for a link between the Danish islands, A. F. Tscherning, was no random person. He had a few years earlier been appointed minister of war at a time when part of the country rebelled, but the Kingdom partially defeated the rebels despite their help from German Confederation soldiers. Tscherning was party chairman of the Peasant Friends. His great interest in technical systems was likely due to his engineering background and his work abroad. In his speech he dealt mostly with the link between Zealand and Funen, where he believed that the solution to the compound was a tunnel. He believed it could be built in the same fashion as tunnels in the mines, and he refuted skeptics who referred to the Thames Tunnel. Construction began in 1825, not to be completed until 1843 after many problems.

Below is an extract from the shorthand minutes of his speech. This is also a comment from another member of parliament, the well-known theologian and hymn writer Grundtvig. "At first glance produces the Great Belt as it seems, almost insurmountable obstacle; I have for many years thought of this matter, and the more I thought about it, [...], the more it seemed to me as if the task is easier to solve than is the first moment could assume. [...] I will only say that in my mind is a subsea link between Zealand and Funen (Grundtvig: It was a long tunnel!). Yes, it is even not such a long tunnel. It must be well to notice that it can be divided into a few portions, and also it is well to keep in mind that in the large mine galleries daily used to extract [...] coal, are lengths of galleries, which are much more

The map shows the railway lines in Denmark in 1875.

Most of the white area was lost in 1864 in a war against Prussia; a large part came back to Denmark in 1920. The arrow shows Little Belt.



significant than the ones here are questions about."¹

A tunnel under a portion of the Great Belt was first realized 141 years later. The connection between Funen and Jutland they would only have to wait 80 years on. It was not actualized in 1855 because the railways did not yet exist as a connection. No one even considered that horse-drawn carriages and pedestrians should have a bridge.

There had been talked about plans for a railway in Jutland since 1852 after the successful tracks in Altona-Kiel opened in 1844 and from Copenhagen to Roskilde in opened in 1847. Of course, they decided, technical progress should also come for the largest part of the kingdom, Jutland. The only problem was the route. Some wanted a location in the middle of the peninsula, while others wanted the train to run between the rich eastern market towns with ports. The middle soluti-

on would benefit the development of the little-populated areas. However, it was the then Secretary of War who decided on an eastern route. He had seen how the railways were an excellent means of transportation to move troops and supplies, so he demanded that the railway go through the fortress city of Fredericia. It proved through many years of debates in parliament impossible to agree on a route in the then democracy's largest and longest discussions. A sort of compromise was decided in 1857. The first piece of the Jutland rail would be Aarhus, Denmark's second largest city, and the rail would run westward into the country. In this way, a large part of Jutland was connected via steamship from Aarhus to Korsør, where the train could carry them on to Copenhagen. At the same time, this solution failed to consider the remaining routes. Parliament succeeded in 1861 to establish a location. This time Fredericia came on the route.



The painting shows Little Belt with the town Middelfart. The first regular steam powered ferry on the belt came in 1861.

At the same time, it was decided to establish rail on Funen from Nyborg and Middelfart. In this context, it was decided that the ferry from Funen should not sail from Middelfart and to Snoghøj, but had to sail to Fredericia due to military considerations.²

Hereby the railway Aarhus-Randers opened in 1862 and Nyborg-Middelfart in 1865. In 1866, the railway continued to Strib, because it was here the ferry to Fredericia should sail. This is due to the country's great attention to Denmark's defense after the ignominious defeat of the German and Austrian troops at war in 1864, when Denmark lost Schleswig. At the same time, this loss changed the country's orientation; while the train had previously run to the south towards Hamburg, this had now become a foreign country. A new connection in the kingdom was to go to the west and north of Jutland. Many years passed before the plans for a bridge were current.

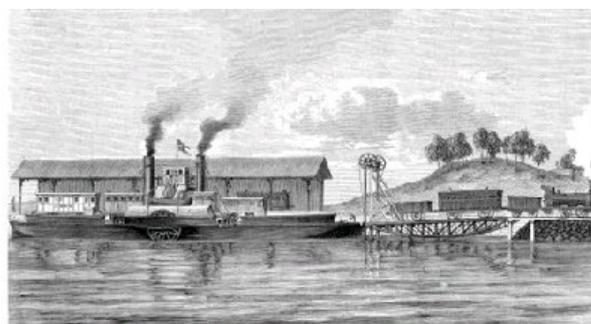
The second plan

Gradually, Jutland and Funen were spun into the overall rail network, and transport of both passengers and goods rose sharply. In 1872 a steam ferry was introduced, crossing from Strib to Fredericia, which could carry railway wagons. Passengers had to get off at the respective stations in Fredericia and Strib to board the ferry or else wait until they could again

embark on a train on the other side. Traffic over the water rose sharply, and the Danish State Railways could see that a bridge would be a great advantage. State Railways began in 1883 to explore ways to build a bridge. Measurements and soundings were made in the area, current and soil conditions were studied, and passing ships were counted. Although narrowest point of the river was up to 40 meters deep and the banks were steep, the base was of solid clay.

The water's flow velocity could be up to 5.7 kilometers per hour, allowing for strong ice packs in hard winters. Among this and other reasons, the narrowest point of the belt was identified as the most appropriate for a bridge because the ice was broken on both sides while bolting happened elsewhere. Measurement of ships included the height of the ships' masts, which would lay down an average height of 33 meters. Parliament drafted a proposal for the bridge. The location was a little away from the narrowest point, for here was the water depth only 29 meters. The bridge was double-track with a central station for the railway in Taulov. The bridge was 840 m long, measured from abutment to abutment, and to this was spans of smaller lengths on both sides.

The superstructure would be created in wrought iron as parallel dragons with composite grids. In total the iron alone weighed 11,000 tons.³

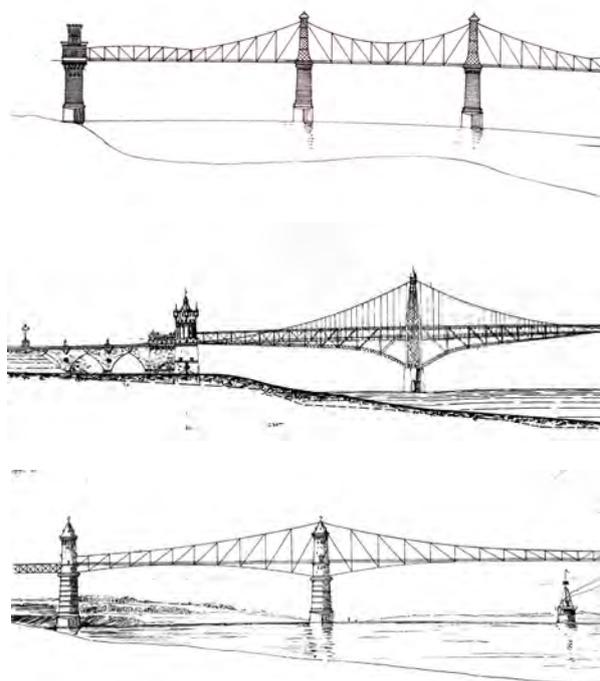


In 1872 came the first ferry that could transport train waggons.

The proposed bridge was prepared by the national railway company themselves, which now had a comprehensive enterprise as the owner of the bridge building field. Most bridges at the time spanned only small streams, but already in 1879 a 352-meter bridge across Limfjorden at Aalborg was inaugurated. It was a low bridge, which had a swing component so that ships could sail through the waters. It was a bold construction at a time in which, among other things, the building of stream pills at a depth of 34 m was complicated and also dangerous.⁴

However, there was little consensus in parliament if there should even be a bridge. Great resistance to the idea arose from local teams in Fredericia. One of the many arguments against the bridge was Fredericia's military importance. As was stated in a newspaper article in Fredericia Dagblad in 1884, the city had been an important point by ferry from Strib and by rail to the rest of Jutland. The fortress likely had little of this military importance any more, but in the event of mobilization, it would be used as a rallying point and required a military installation of a certain size. If, in the event of a crisis, the compound of Fyn were moved to Snoghøj, the military gathering should also be relocated thereto. Therefore, these teams argued, the bridge needed to have some protection so that it at least could be defended until the military forces on Funen had been moved. Of course, it was also conceivable that the bridge would be blown up in connection with the defense of Funen. Overall, however, the authors claimed that no war ministry would permit the building of the bridge.⁵

The local newspaper highlighted several other arguments against the bridge, namely the city's interest in maintaining the ferry service, which employed many salaried state workers in the city including postal employees. The train station restaurant also meant a lot to the city. As things were, the passengers were forced to wait for hours between tra-



Many suggestions were made in the second plan for the bridge. The technology behind the construction was cast iron.

ins and ferries, and the region's farmers and merchants supplied the restaurant with meat and groceries.⁶ Whether it was due to the resistance from the eastern part of Jutland is not known, but the proposed plan was presented to parliament in 1886 only to be rejected.

The third plan

Traffic on the railways increased constantly. The cost for transport over longer distances went down, taking advantage of a population made up of an increasing number of travelers. The ferry connection over the Little Belt was still a bottleneck, despite the deployment of more ferries. In 1899, the national railway company drew up a new proposal. This time it was a single-track railway bridge, which made the bridge less expensive. More important was the ever-increasing amount of traffic towards



The town Fredericia at Little Belt was a fortress. Of military reasons the railway ended here and the ferry to Fyn went from here.

Germany and Jutland. If a bridge was not build, instead it would be necessary to invest in a ferry from Gedser to Germany and from Kalundborg to Århus.

Technical progress in bridge construction was rapid during this time period. The use of now cheaper and lighter steel alone meant that the bridge could be constructed much more easily. Steel could be produced in varying levels of hardness, and the quality was much more uniform than that of the previously proposed wrought iron. The lighter weight of the steel also meant the use of larger spans. Thus was the construction no more bound by having to place the bridge at the former place with 29 m water depth. Instead, they could build the bridge at the shortest distance; the longer span meant that the pills could keep the same depth as the original project. Hereby, the bridge was only around 750 m; in all 100 m shorter than the version previously proposed.

Two types of bridges were proposed. A suspension bridge with stiffening bar would cost 15.6 million Danish kroner (Dkr.) in contem-

porary money. An estimate was also prepared for a cantilever bridge, which was characterized by the bridge's beams balanced on pillars in contrast to a bridge with a total span; this type of bridge was invented in 1866, and the best known example at that time was the railway bridge Firth of Forth Bridge opened in 1890 in Scotland. A bridge built on these principles and with a curved top and bottom was calculated to be 300,000 kr. cheaper. Both bridges would only require three spans and the associated land connections. While the first proposal envisaged a land height of 33 m, the proposal now wanted 42 m, a model that had been used in the German bridges over the Kieler Channel.

As the Minister of the Interior presented the matter in parliament, he argued that "all indications are that the disadvantages still will grow, so that the situation in the near future will prove unsustainable. In this respect, it is particularly significant that almost all the increase of persons is caused by the fast trains, with the result that the corresponding ferries especially in summer are constantly overcrowded. To that end there could well be remedied by sending extra ferries, but this causes loss of time and provides an uncertainty as to train precision that cannot be reconciled with the requirements of a fast and convenient passenger."⁷ He could also have mentioned that freight had increased 20-fold since the connection via steam ferry had opened in 1872, and passenger traffic had tripled. Because of the 1898 adoption of a third ferry at Strib, the Minister stressed that this new solution needed to be more than a purely temporary measure and that it should not exclude the construction of a fixed bridge.⁸

The Minister had been granted 60,000 Dkr. to complete the plans. Despite the pitance, however, the proposal was rejected, even though similar authorization was given to other controversial issues around a freight railway station in Aarhus and the expansion of the railway station in Esbjerg.

Plan number four

The political game surrounding the bridge was due to a mixture of local political interests to defend the constituency relationship along with a desire to create a balanced transport system within the available limited resources. The debate also discussed the safety issues of a bridge, where the later so infamous Minister of Justice Alberti referred to the Scottish railway bridge in Tay, which during a storm in 1879 broke down and sent a train full of passengers falling down.⁹ Military considerations also entered into the debate, in which a "hostile power [could] send a ship up here and one, two, three, shoot this bridge to pieces" to prevent the connection between parts of the country, so that soldiers could not reach the fortress in Copenhagen on which the country's defense largely was reliant. Overall, however, the politicians wanted distance traffic to be conducted with good, consistent, fast trains, so that people should at most travel only a half day to go from one outer edge to the other of the relatively lengthy country.

In 1904, parliament discussed the ways in which the ferry service to Germany from Gedser in 1900 had not taken the pressure of crossing at the Little Belt - maybe because of the lack of a bridge at Madsnedø. Traffic had increased over a year by approximately 190,000 goods items and 30,000 travelers. At the same time, Fredericia had a problem contrary to the other ferry places in the country because it was a crossing station twice a day by two o'clock. At the station, the main trains gathered where not only many passengers but also postal, baggage, and sleeping carriages were to be transferred in a very short time. Ferries had been extended, and several ferry berths had been built, but traffic was close to the maximum for the technical facilities, ferries, and space in Fredericia, the commission concluded. Only a bridge having double tracks would resolve any future increase in goods and passenger traffic, it was concluded. The trains would save at least half an hour in

transport, and passengers were free from to go from the station to the ferry, the distance between which was quite long.¹⁰ Discussions concerning a bridge and a double track to Fyn were coupled with the possibility of establishing a ferry connection between Refsnæs and Hou. This would allow traffic from Zealand to



The bridge over Little Belt should be near the smallest distance between Jylland and Fyn. The map shows the suggestion from 1923 with new railway tracks.

skip Fyn altogether, thus taking pressure off of the Little Belt.

Again, a number of years passed, but the ferry crossing continued to be a problem. A double-track railway to Fyn was adopted in 1908, but without any plans for a bridge. In 1917, the National Railway Company again made a proposal for a bridge, this time at a cost of 20 million Dkr., but the official plans for the bridge came from Parliament with the Act of 1918.

At that time, however, a major political event occurred that changed the conditions of the links in the Kingdom. In the aftermath of the peace after World War One, Denmark was granted control of a large part of the former

Danish kingdom, Southern Jutland. Therefore, the connection south in Jutland became important once again. Before 1920, the National Railway Company had prioritized a bridge over Storstrømmen between Zealand and Falster, but with the new province the political scene was tipped to emphasize the Jutland connection. A decision was not made immediately, even though the calculations showed that a bridge for approximately 38 million Dkr. would provide an annual saving of 2.4 million Dkr. in costs for the expansion of the ferry service alone. However, a grant for a feasibility study with mapping, including aerial

stances the ships anchored up to wait for better weather, ships from the south usually anchoring at Galsklint and those from the north choosing Lyngs Odde. When conditions were once again favorable for passage, ships often moved as a single squadron through the belt. Therefore, an eastern bridge localization rather than a western one was identified as optimal for the voyage.¹¹

In contrast, studies of soil and similar fixed ratios were similar to those that had been conducted in the past, but in repeating the tests, facilitators could be absolutely sure that the



In 1923 the political attitude was now positive for a bridge. As before was the proposal only for a bridge for trains.

photography of the area, was finally approved.

It may be surprising that many of the studies that had been conducted on the previous proposal were now duplicated. One can understand the census of ships in the waters, which had changed drastically in the composition of vessel types. Thus, there were a much higher proportion of vessels with mechanical driving force, just over 70%, but the 30% of sail-maneuvering ships were also observed, as their sails influenced the planning. Less than 1% of these ships had masts higher than 32 meters, so the plans need not hold much regard for ships with higher masts. Sailing patterns showed that the ships took advantage of the entire belt, which they could do because of the great depth that ran along all of the coasts. However, it was difficult for ships to sail in the narrow part of the belt, when there could be fierce northwesterly winds and a strong southbound current or by strong easterly winds and a hard northbound current. In such circum-

measurements were correct. Bridge building in large dimensions was relatively new, and many new materials and bridge constructions were used. Several similar bridges had collapsed. One of the largest was in 1907, when the Quebec Bridge collapsed due to the senior engineers' incorrect calculations. That bridge had been built to the same principles as the proposed Danish bridge. The Canadian bridge was (and still is) the world's largest cantilever bridge of 549 meters. The bridge was dogged by accidents: in 1916, as the reconstructed bridge had its final bridge span put in place, it dropped the subject in the water. The span was not salvageable, so an entirely new section had to be built, which was especially problematic in the midst of the World War, when the demand for steel was great.¹²

The newest geological studies confirmed the earlier measurements: the existence of a stable ground under the water on which the bridge could be built. There were a few areas with



The suggestion for the bridge in 1923 included a hang ferry for three cars. The model was taken from a German bridge in Rendsburg, that still today is in action as shown at right.



less suitable soils, but these issues could be solved. Measurement of flow velocities showed speeds of up to 2.25 meters per second, but also that there was a counter-current along the coasts, as ships took advantage of when sailing against the mainstream; this aspect was also addressed in the decision of the bridge location. The passaged vessels were counted, which an average of 1,000 per month. Of the counted 5,000 ships in total, only 20 had a mast height of 33 meters or more.

In 1923, the Sailing Ship Owners of Denmark had requested a bridge height of 35 meters, but when the bridge was adopted, they wanted the bridge to be even higher. At the same time, the organization wanted a guard and a tug positioned at the bridge. After national railways had counted the number of ships and measured their mast height, they decided to go back to a bridge height of 33 m. This saved 5 million Dkr., and the taller ships had an alternative option to sail through the Great Belt on the way to Baltic ports.¹³

A revised plan

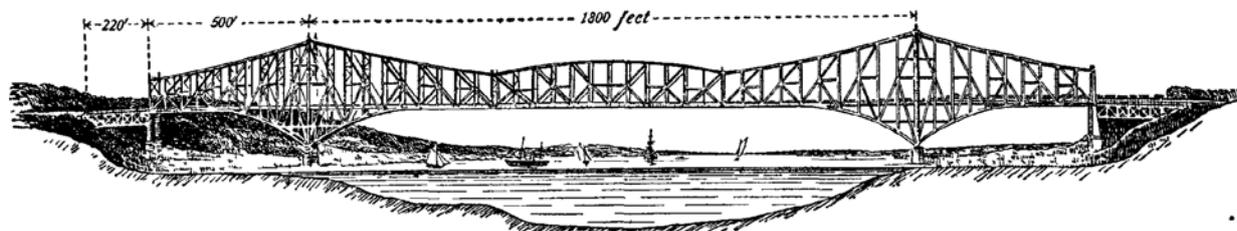
It was finally decided that the bridge should be a high bridge. This decision was quite a bit more expensive than a lower bridge, but a low bridge would need to be able to be opened for ships, which would cost in the form of a fixed staffing. At the same time, a low bridge was much more vulnerable to collision, and in the worst case, traffic between parts of the

country could be stopped for a long time if the bridge should need to be restored. An opening of a railway bridge was also not appropriate in the interests of train schedules.

A road bridge actually meant the planning of The National Railway Company could not be paid. There was in 1922 a transfer by the ferries of approximately 20,000 cars annually and the planners from the railway company figured only with that number could be doubled - they should be wiser.

Finally, in 1923, the government presented a proposal for a railway bridge. The traffic on the ferry had grown even larger, with approximately 750,000 paying passengers over the belt and with 34 ordinary daily trains. During the war even larger quantities were transferred, but the effects had also been delays and aggregation of goods on a large scale.¹⁴ Concern for motorists was partly taken into account because a double hang ferry was included. Each ferry could take two of the present small trucks or three cars of size Ford T. A ferry could make 12 trips per hour, whereby it could transfer 36 cars.¹⁵ The bridge on the Kiel Canal in Rendsburg had a similar hang ferry. This bridge was a high bridge with long cables for the hanging ferry, while the ferry planned for the Little Belt would hang just below the bridge.

The following year, the Danish Parliament finally decided on the building of a bridge. The price was estimated at 15 million Dkr. Prices



For the planning of the construction was used experiences from bridge building around the world. The new steel and new construction systems should be handled carefull. Experiences from the Quebec Bridge in Canada were included. The bridge collapsed in 1907 and again in 1916 before it was finished.

for a bridge with larger piers, allowing for the building of an overpass for cars later, were estimated at 16.5 million Dkr., and a combined bridge with both road and rail was estimated at 23.5 million Dkr., but the government did not find these options to be worthwhile. Automobile taxation was so poor at the time that there were too few funds to finance the road section of the bridge, and it was unthinkable for The National Railway Company to finance a bridge for their competitors, so these options were ruled out. The bridge project acquired some of its financing by delaying the expansion of some originally planned double track around the country and by stretching construction out over 10 years, allowing the bridge to be built without foreign loans.

The National Railway Company continued with advanced stages of planning. Excavation work started in December of 1925, and in 1927, the National Railway Company offered an international tender for the double-track railway bridge.

A revision of the revised plan

However, general opinion within the population began to call for a road bridge. The need arose slowly. A private ferry was established in 1902, which first conducted tours in the summer, but gradually the need for transport in the remaining time became so great that, in 1912, the company inserted a car ferry on a regular service from Middelfart to Snoghøj. The ferry could include four cars, and the initiative was supported by the union of Danish motor owners, FDM. After a slow start, with few more than 2,000 transferred cars in 1916, the number certainly rose, and the company renovated the ferry to hold 8 cars and acquired an additional ferry to hold another eight. In 1919, the ferry transferred more than 13,000 cars; over 20,000 cars were transferred in 1923; and 139,000 in 1934. The ferry became a gilt-edged investment, shares in which reached a dividend of 300-400% in the last year.¹⁶

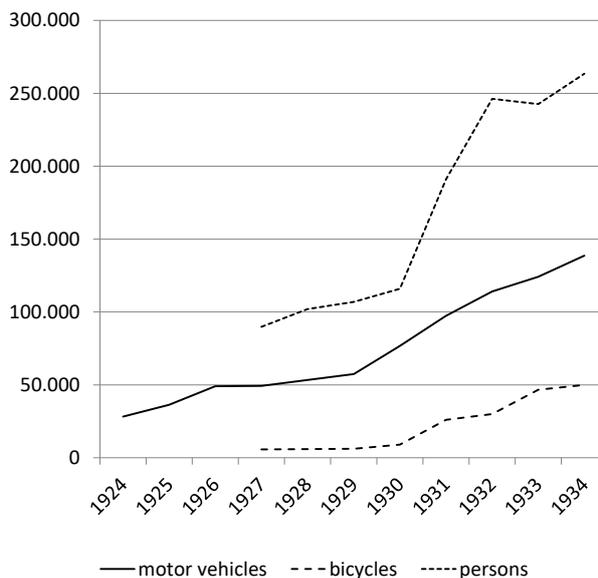
The strong need for crossing also convinced others to take car traffic seriously. The State



The traffic with the ferries increased enormously since the 1920's. The planners had the problem: how much would the traffic of automobiles rise?

Railways railway ferries also began to include motor vehicles when there was room. During the first years, the cars' gasoline was drained into bottles with the inscription "To be carried by hand." The driver had to stand at the railing, and in the case of fire, he would throw the containers into the water. Motorists were unhappy with the high fares of the two ferry routes, and a private ferry crossing was therefore at Strib-Fredericia in 1923; motor organizations were highly active in its foundation. Although the ferry had room for 6 cars, the volume of vehicles moved was quite as great as that of the competing ferries from Middelfart. In 1924, the private ferry transferred 14,000 vehicles, and in 1934, 50,000 vehicles were transferred. The State Railways ferry did not discuss these statistics; in 1934 they transferred almost 6,000 cars and 2,500 motorcycles.¹⁷

After the First World War, road transport gained a certain scale, and the motor organizations became significantly more active. FDM approached the government in 1919 with a proposal for a combined traffic and railway bridge. The local traders' association in Middelfart initiated a petition in which almost 500 organizations urged the government to take into account the drivers on the future brid-



ge. When a new plan was discussed in 1923, the association sent another request to parliament to ensure that the bridge also became a bridge for road transportation. The hang ferry was no solution, for it did not matter for the motorists whether a ferry was sailing from a port or driving under a bridge.¹⁸ The hang ferry system would not meet the need, for the expected 50,000 vehicles in 1926 would burden the ferry with 40,000 in the summer months in the period from 7 in the morning to 9 at night, with which the hang ferry system could not cope.¹⁹

A parliamentary committee set up under the Act of the bridge building took only a few months to part with the decision that motorists should be satisfied with the hang ferry. They wanted a real bridge for road transport.²⁰ They were not alone, and the protests continued to come. In the spring of 1926, for example, Funen motor people gathered at a meeting at Kongebrogården near the future bridge construction site. All agreed that there should be a bridge for road transport. It was pointed out that when the plans emerged, 20,000 cars were transferred annually, and this number was expected to double. In 1926, the number reached 100,000 cars. The many participants unanimously adopted a resolution, and after

a drive around the beautiful countryside they ended the day with dinner and dance.

The Minister of Transport noticed the growing criticism, and he aired the possibility that the future bridge become a combined rail and road bridge; the ground at the bridge could be covered with a plank covering, so cars could drive over when no trains used the bridge. It was in fact a solution that had been used at other bridges. For example, in 1904 a bridge



In the end the Little Belt bridge became a bridge for trains and automobiles. In 1935 it could be opened.

was built over Mariager Fjord where the road had to run when trains were not driving.²¹

The director from FDM supported the proposal, but it was not a solution with which everyone was happy. The National Railway Company did not want automobiles to disrupt railway driving, and FDM's vice president went against the organization's director and publicly stated that he did not want to wait in line if there was a train in one direction or another. Critics also pointed out that a railway bridge at Little Belt was much busier than the mentioned bridge was.²² Funen Stifts Motor Union and Jysk Motor Union held a large protest meeting at Snoghøj with 3,000 participants in June of 1927. They had good arguments on hand, for the number of vehicles moved was

so large that one could demonstrate that the bridge could now pay off as a road bridge.

There soon began a political game in which the politicians wanted to expand the rail bridge with a road bridge, but in which motorists would have to pay for the bridge. One point of contention was the total amount that such a bridge would cost. The National Railway Company had calculated that the extra cost would be 7.5 million Dkr. The Secretary-General in the other motor organization, Royal Danish Automobile Club (KDAK), Captain Ipsen, believed that a road bridge alone would cost only 3-4 million Dkr. FDM went further and suggested that drivers should build their own bridge west of the planned state rail bridge. FDM hired a port engineer to prepare a proposal for a suspension bridge, and because a motor bridge did not need to be particularly strong, it could be built at the narrowest point, so there could just two piers. In total it would only cost 6 million Dkr. The planned bridge could carry two dense rows of great contemporary 4-ton trucks with full loads, in total 1,000 tons, but the dimensions could be slighter still, whereby the bridge would be even cheaper.²³ Maybe it was the motor organization's proposal for a cheaper bridge that was the reason the cost of the road section on the State Rail bridge was later reported to be 1 million Dkr. 6.5 million Dkr. lower.

The bridge was suggested to be financed through tolls. This method had been used for the road bridge over the fjord in Aalborg, but the Director General of The National Railway Company was still afraid of this solution, as he believed that drivers would do everything in their power to be free from tolls, and so wanted The National Railway Company to pay this amount in some way.²⁴

In the spring of 1927, the Minister of Transport presented a proposal for a combined rail and road bridge. The railway bridge was otherwise distributed in bids, but companies were asked to wait to submit offers until the final design was ready. The financing of



the additional cost of the road bridge had to be negotiated, and was finally settled to be repaid with an annual fee of 500,000 Dkr. from vehicle taxes supplemented either by bridge tolls, rubber tax, or gasoline tax.

In 1927, a plan to take money from annual circulation taxes and establish a gasoline tax of 7 øre per liter was adopted. An income of 27 million Dkr. was expected for 1928, but the increasing use of cars moved the revenues to 36 million Dkr., and two years later it had reached 50 million Dkr. Therefore, a move to finance not only the Little Belt Bridge but also many other bridges resulted, and these continued to be built until 1950. There was, however, put a penny as a tax on each liter petrol, when the Oddesund Bridge and the Storstrøm Bridge would be built, but in return all ideas about payment via a toll disappeared. The payment to pass the bridge in Ålborg disappeared when the bridge at Lillebælt was inaugurated.

In addition, due to political reasons, the state railways began to consider taking a railroad through Fredericia, building a whole new

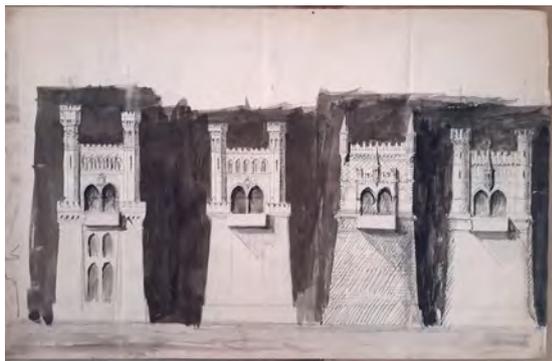
station. This added a significant portion of the cost because the citizens had been very much against the whole project, and this added an additional cost of 10 million Dkr. out of the estimated 33 million.²⁵

Experience from similar foreign bridges was used in the specific design of the bridge. Mainly bridges in the United States but also bridges in Russia and Germany were taken as references. Plans and construction details were obtained for each of these bridges. Data on planned but not yet realized bridges, for example, a bridge across the Channel between France and England, was also analyzed.²⁶ Lessons for certain parts of the structures could be retrieved from areas other than bridge construction. Thus data on the foundations of a torpedo testing station in France was included in the analysis for its use of the caisson of reinforced concrete.

The bridge came in a new tendering in 1928, and in December the contract could be signed; the bridge was to be completed by the end of 1934. The consortium was dominated by German companies, with Krupp as a sup-



The architecture changed from the first sketches in the 1800's to the very simple expression in 1935.



plier of steel. The plan did not comply completely with the contract, but on May 14, 1935, the bridge's inauguration took place with King Christian X in the lead. The economic plans did not hold steady. The entire building project cost 42 million Dkr., where the railway bridge included 16.7 million, the road bridge 7.5 million, the roads 1.6 million, and the connected railway installations 16.5 million Dkr.

Conclusion

The events surrounding the Little Belt Bridge show that the planning of major traffic infrastructure is subject to conditions that change over time.

International politics

The political conditions changed a great deal, first with the loss of Holstein and Schleswig's association with the Kingdom of Denmark and second with the aftermath of World War 1, during which Southern Jutland was re-integrated into the kingdom. The first incident meant a downgrading of relations over the belt, while the second incident meant a strengthening.

Military considerations

The severe defeat in 1864 meant a strong focus on military considerations. Therefore, it was decided that the railway ferry's first running from Fyn should go between Strib and Fredericia. Even in the 1800s fortresses were strategically important, with fortifications around Copenhagen as the country's most important, as this was where the military could secure its position and be ready to counter-attack. The fortress in Fredericia had lost its importance as a real fortress, but it was quite important as a temporary bridge while soldiers gathered on the road to Copenhagen.

Local politics

All politicians in parliament struggle to benefit their regions. Particularly strong political battles were fought to not lose such benefits, and there is a certain conservatism based on historical conditions for instance Fredericia have had great benefits from being a hub for rail and ferry. Part of the resistance to the bridge was because due to the city's reluctance to losing its ferry service. In the end, the city was compensated by rail route running through it, allowing it to retain some traffic significance.

Prioritization of the overall traffic pattern

Some very general terms were naturally included in parliament and the government's deliberations. The funds were constantly limited and the decision-makers had to prioritize between different options. The state railways and the government had long prioritized a

A new bridge was built in 1970. Today 70.000 cars are passing each day - the planners thought in 1922 that 40.000 cars would be transferred a year!



connection to the south, so that Zealand was connected to Falster. Thus, the bridge at Madsnedssund for the railway ferry to Falster could be built in 1883 and established in 1884. The further bridge at Storstrømmen was prioritized higher than that at the Little Belt. These priorities changed when Jutland again became part of the kingdom. Ferry service also entered into the equation as an alternative to the Little Belt Bridge with the Hou-Refsnæs ferry, but the Korsør-Aarhus and later Kalundborg-Aarhus routes also complicated the puzzle of the overall traffic.

Technological change by shipping

The biggest technical change was the introduction of power. Steam ships increased in number throughout the period under review, but reflections on sailing ships were included even in the planning period for the final bridge. Although their importance was on the decline, mast height was taken into account, and the bridge's final position paid attention to the best navigation conditions for sailing ships. The Sailing Ship Organization's special requests for pilots and rescue were not met, so the profession was strong no more.

Technological change by road transport

An important change occurred in transportation, especially after the mid-1910s. Carriage

transport had not yielded any particularly strong desire for fixed links between the regions, but with motor vehicles, traffic switched from the local to the regional and national levels. The two motor organizations handled the motoring interests, and in the early 1920s motoring was so strong in the public mind that politicians had to take it into account. This meant at first that a system hang ferries was built in 1923, that the possible future extension of a road bridge was considered by the idea of building stronger piers in the present in 1924, and that finally in 1927 a motor bridge should be included in the finalized bridge plans.

Technological change in building bridges

Enormous change occurred in the building of bridges. One of the major innovations came with the advent of industrially produced steel as a replacement for cast iron. At the same time, bridge-builders experimented with new forms of construction, and theoretical calculations of bridges replaced former more evidence-based efforts. Reinforced concrete joined by foundations and many other new tools and techniques came about. All these things made bridges less expensive to build while simultaneously allowing for the widening of spreads, meaning the bridge could be placed more appropriately.

Architectural change

Finally, it must be mentioned that architectural expression changed very dramatically over the period from the bridge's conception to its eventual building, moving from the classical style inspired by medieval castles to the final bridge very pure, almost minimalist expression with a long, straight construction of bridge spans and piers of sleek surfaces.

Looking at the process behind this bridge, it is interesting to see that at no time in history were the planners able to foresee the future more than a decade ahead. In 1922 the planners imagined a future with 40.000 cars a year passing the bridge – today this is the traffic in less than one day! Planners in the state railways continually carried their wants, but politicians stalled the most. Seemingly the most planned and regulated conditions suddenly lost importance to before-unknown factors. Of course, this did not prevent the decisions from being made. In this case, the Little Belt Bridge took many years to be fulfilled, but when it was necessary in 1970 to supplement it with a larger bridge, the 1,700 meter long bridge was solely for cars; the train traffic could still be handled by the old bridge.

Notes

- 1 Folketingestidende 1855, 1st. behandl. af forsl. om en jernbane i Jylland.
- 2 R. Berg: Dansk Jernbanepolitik i Tiden fra 1850 til 1865. I: Nationaløkonomisk Tidsskrift, Bind 3. række, 6 (1898) og Middelfart Avis 11/10 1927.
- 3 H. Flensborg: Forslaget til en Lillebæltsbro. I: *Ingeniøren*, nr. 49, 1923.
- 4 Sanne og John Juhler Hansen: Et eventyr i stål og beton. 1996.
- 5 Fredericia Dagblad, 23/10 1884, s. 3.
- 6 Fredericia Dagblad, 15/10 1884, s. 3-4.
- 7 Folkebladet Sydjylland 26/1 1899. Retskrivningen er lettere moderniseret.
- 8 Folketingets forhandlinger 1899, sp. 2379.
- 9 Henrik Harnow: Jernbroer med historie. I: *Ingeniøren* 10/3 1995.
- 10 Kommissionen angaaende Anlæg af nye Jernbaner. Referat af Kommissionens Forhandlinger. 1904.
- 11 Svend Brannov: Forundersøgelser for Lillebæltsbroen 1923-1924. I: *Ingeniøren* nr. 4, 1925.
- 12 Wikipedia, opslag Quebec Bridge.
- 13 Sanne og John Juhler Hansen: Et eventyr i stål og beton. 1996.
- 14 Folketingets forhandlinger 1923.
- 15 Middelfart Avis 10/5 1926.
- 16 M. Bygbjerg: Middelfart Dampskibsselskab 1902-1935. 1935.
- 17 Åge Petersen: Strib i færgernes og jernbanens tid. 1971, Statsbanerne: Virksomheden 1934-1935, Sanne og John Juhler Hansen: Et eventyr i stål og beton. 1996.
- og Poul Thiesen: Da Fredericia var færgernes by. 1974.
- 18 Middelfart Avis 10/5 1926.
- 19 Brev til Folketinget 13/2 1924 fra KDAK og FDM.
- 20 Jyllandsposten 24/1 1924.
- 21 Nationaltidende 31/5 1926.
- 22 Aarhus Stiftstidende 8/6 1926.
- 23 Middelfart Avis 9/2 1927 og Aarhus Stiftstidende 11/2 1927..
- 24 Jyllandsposten 8/5 1926.
- 25 Middelfart Avis 11/10 1927.
- 26 Brobygningssager, Danske Statsbaner, Baneafdelingen, 1911 Lillebæltsbroen – 1925, Rigsarkivet.