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Annex 2 to the consultation paper pursuant to Articles 8 and 9a EIA Act (UVPG)

Excerpt from Annex 1 – explanatory report – to the application documents for the plan approval procedure section 3.6 – comparison of the main solutions – choice of alignment

English version

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List of abbreviations

B – E – E	Bridge between the landing points →F-E and →L-E
B	Highway designation
Cf.	Compare to
E	European road designation
EIA	Environmental Impact Assessment
EIA Act	Environmental Impact Assessment Act
F-W	Relatively low-conflict corridor/Fehmarn-West landing point
F-NW	Relatively low-conflict corridor/Fehmarn-Nearwest landing point
F-H	Fehmarn ferry harbour landing point
F-E	Relatively low-conflict corridor/Fehmarn-East landing point
FBFL	Fehmarnbelt Fixed Link
Fig.	Figure
i.e.	That is
K	Regional road designation
L-W	Relatively low-conflict corridor/Lolland-West landing point
L-H	Lolland ferry harbour landing point
L-ME	Lolland-Mideast landing point
L-E	Relatively low-conflict corridor/Lolland-East landing point
LBV-SH	State Agency for Road Construction and Transportation Schleswig-Holstein
T_A - E - ME	Immersed tunnel between the landing points →F-E and →L-ME
T_B - E - ME	Bored tunnel between the landing points →F-E und →L-ME
Tab.	Table
TBM	Tunnel boring machine
VVM	Vurdering af Virkninger på Miljøet (Danish environmental impact assessment report)

3.6. Comparison of the main solutions – choice of alignment

3.6.1. Solutions considered

In Section 3.4, the most suitable alignments for tunnel and bridge solutions were identified. Due to their different environmental effects, both the immersed tunnel and the bored tunnel solution will be evaluated as part of this comparison of the main solutions. When the long approach bridges are taken into account, suspension and cable-stayed bridges do not have significantly different effects on the environment. It is therefore sufficient to consider only the most technically and economically favourable solution, the cable-stayed bridge. Consequently, the comparison of the main solutions examines three solutions:

1. Immersed tunnel (T_A – E – ME)
2. Bored tunnel (T_B – E – ME)
3. Cable-stayed bridge (B – E – E)

3.6.2. Alignment description for main solution 1: the immersed tunnel

Originating from the existing B 207/railway transport system, the main solution immersed tunnel begins on Fehmarn to the northwest of Bannesdorf. The rail alignment curves in a slight easterly direction before proceeding in a straight line towards the Baltic coast, reaching the shoreline to the east of the ferry harbour. The new motorway (E 47) initially deviates slightly to the west to create space for the new Puttgarden junction. It then follows a slight curve to the right, before crossing the existing railway tracks to the south of the former shunting yard and then joining the new rail alignment to the west. The actual tunnel structure begins approximately at today's coastline and run in a very straight line towards the Danish coast, reaching it about 1 km to the east of Rødbyhavn. On Lolland, the rail alignment curves slightly to the right before linking up with the existing Rødby – Sakskøbing rail line some 5 km later. The E 47 retains its elongated form on Lolland and re-join the existing E 47 alignment on a level with the southern edge of Rødby. The immersed tunnel is shown in Fig. 3.8.

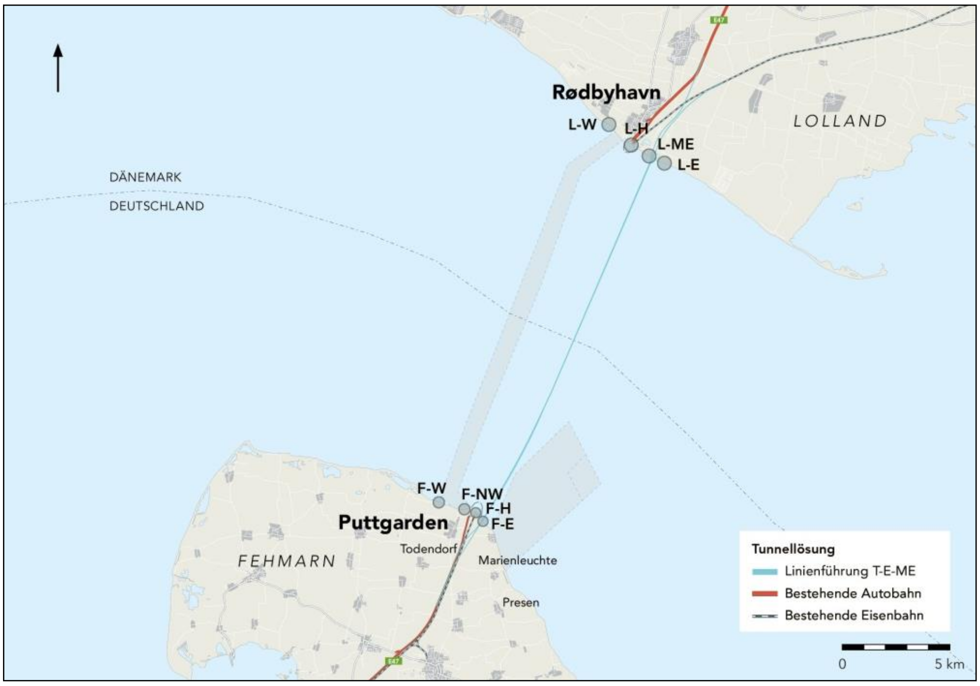

Fig. 3.8: Immersed and bored tunnels – an overview of the alignment

DÄNEMARK	DENMARK
DEUTSCHLAND	GERMANY
Tunnellösung	Tunnel solution
Linienführung T-E-ME	T-E-ME alignment
Bestehende Autobahn	Existing motorway
Bestehende Eisenbahn	Existing railway

With the exception of the trough sections leading to the tunnel structure, the rail alignments stick closely to the terrain on Fehmarn and Lolland. The E 47 also follows the terrain for the most part, with the exception of the trough sections and the overpass over the railway to the south of the shunting yard. The tunnel gradient in the Fehmarnbelt follows the seabed.

The secondary networks on Fehmarn and Lolland have to be adapted to the new conditions. On Fehmarn, this relates primarily to the construction of the Puttgarden junction, the relocation of the K 49 and the new road connection to the ferry harbour from the K 49. On Lolland, dissected roads will be restored and a toll booth will be installed.

3.6.3. Alignment description for main solution 2: the bored tunnel

The main solution bored tunnel runs along a similar alignment to the immersed tunnel. The railway tracks are situated somewhat further to the east, as the need for three separate tunnels causes the bored tunnel to take up a greater area than the immersed tunnel. There are substantial differences to the immersed tunnel solution in terms of the gradient. Due to the required protective layer, the bored tunnel is some 20 m deeper underground than the immersed tunnel, and the tunnel portals on Fehmarn and Lolland therefore are further inland. This also makes the bored tunnel considerably longer than the immersed tunnel (cf. Tab. 3.4).

3.6.4. Alignment description for main solution 3: the cable-stayed bridge

The alignment of the main solution cable-stayed bridge on Fehmarn is largely equivalent to that of the main solution immersed tunnel. As the landing point on Lolland is further to the east, the alignments there also runs somewhat further eastward in comparison with the immersed tunnel.

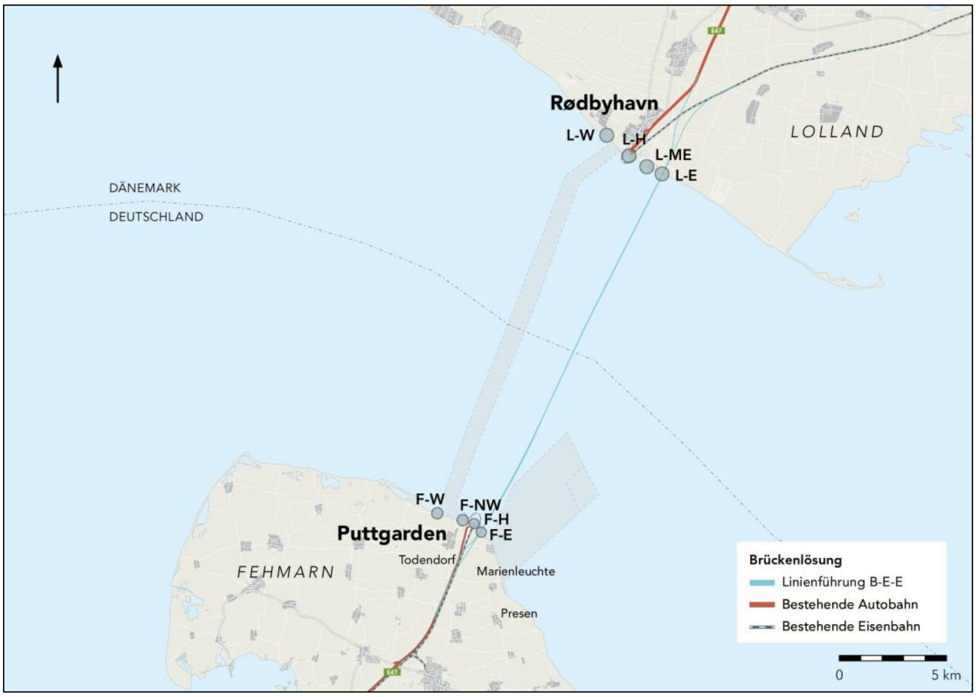

Fig. 3.9: Cable-stayed bridge – overview of the alignment

DÄNEMARK	DENMARK
DEUTSCHLAND	GERMANY
Brückenlösung	Bridge solution
Linienführung B-E-E	B-E-E alignment
Bestehende Autobahn	Existing motorway
Bestehende Eisenbahn	Existing railway

Alignment lengths

The alignment lengths of all three main solutions are shown in Tab. 3.4. It should be noted that the onshore starting and finishing points of the plans are not exactly identical. The finishing point for the immersed tunnel on Lolland, for example, is about 1 km further north than that of the cable-stayed bridge. The finishing point of the road section of the bored tunnel is 250 m further north than that of the immersed tunnel. This is due to the fact that the bored tunnel emerges from much deeper underground than the immersed tunnel. From a construction and alignment-related perspective, the starting and finishing points could be identical. However, the longer rail alignment for the bored tunnel results from the need to join/separate from the existing tracks earlier/later, while taking into account the required switchover between the Danish and German systems.

Tab. 3.4: Alignment lengths of the main solutions

Main solution	Transport alignment	Onshore, Fehmarn	Fehmarnbelt structure	Onshore, Lolland	Total[3)]
		[km]	[km]	[km]	[km]
Immersed tunnel	Road	3.7	18.1[1)]	6.3	28.2
	Rail	3.4	18.1[1)]	5,2	26.7
Bored tunnel	Road	2.9	19.6[1)]	5.6	28.1
	Rail	3.1	21.2[1)]	4.3	28.6
Cable-stayed bridge	Road	4.2	17.6[2)]	5.1	26.9
	Rail	4.2	17.6[2)]	5.1	26.9

1) Including cut-and-cover tunnel sections

2) From abutment to abutment

3) The total lengths of the main solutions are different because the alignment end points used in the planning are not identical on account of the different technical requirements.

3.6.5. Weighing up the main solutions, selecting a preferred solution

3.6.5.1. Methodology

With the aim of selecting a preferred solution, the three main solutions are assessed and compared in terms of the following seven factors:

- Environmental impact
- Regional planning
- Traffic
- Urban development
- Agricultural structure
- Construction method

- Costs/profitability

Each assessment area includes several criteria. Objectives are defined for the individual criteria and their achievement is assessed. The assessments of the individual criteria in each assessment area are then combined to form an overall classification by means of verbal/argument-based discussion. This then determines the ranking of the main solutions in each assessment area. The overall result of assessing the main solutions – the preferred solution – is derived from the verbal/argument-based aggregation of the rankings for all assessment areas.

The rankings are as follows:

- The solution placed in position 1 is the most suitable one in comparison with the other two solutions
- The solution placed in position 2 is also suitable, and is placed in between the most suitable solution and the still suitable solution (position 3)
- The solution placed in position 3 is (still) suitable in comparison with the other two solutions, but has more disadvantages than the other two solutions.

When weighing up the different solutions, it should be borne in mind that ranking scales do not give a quantitative reflection of the differences between the results in the various assessment areas. Even though the differences between the rankings in the various assessment areas may vary, they can as a matter of principle only be described in qualitative terms. If two solutions are deemed equivalent and placed in first position, the third solution is ranked third.

3.6.5.2. Assessment area environmental impact

The fundamental goal is to prevent the FBFL from having a negative environmental impact or at least to minimise its effects. The assessments are based on the environmental factors defined in the Environmental Impact Assessment Act, UVPG (people/human health, flora, fauna and biodiversity, soil, water, climate, air, landscape, cultural and other physical assets). A detailed description can be found in the EIA report (cf. Annex 15 to the plan approval documents) and the summary for a general audience (Annex 1 to this explanatory report). Due to the special situation in the marine area, the environmental factors have been broken down further into marine environmental sub-factors.

<u>Assessment – Fehmarn onshore area</u>

Since the three main solutions follow virtually identical alignments on the island of Fehmarn, their qualitative and quantitative effects differ only slightly.

The bridge is ranked first for the environmental factors soil, water, flora, fauna, climate and air, in other words more frequently than the other two solutions (immersed tunnel – soil, landscape, cultural and other physical assets; bored tunnel – people/human health, biodiversity). Conversely, the immersed tunnel is not ranked third for any of the environmental factors, whereas the other two solutions are (bridge – people/human health, biodiversity, landscape; bored tunnel – soil, flora, fauna, cultural and other physical assets, climate/air). The immersed tunnel is ranked second for the environmental factors people/human health, water, flora, fauna, biodiversity, climate/air (bridge – cultural and other physical assets; bored tunnel – water, landscape). For these reasons, the immersed tunnel and the cable-stayed bridge are classified as equivalent in the assessment of all environmental factors. The bored tunnel's slight advantages in respect of the environmental factors people and biodiversity do not offset its less favourable ranking with regard to the environmental factors soil, flora and fauna, cultural and other physical assets and air/climate. In the overall ranking, the bored tunnel is therefore placed in position 3, while the two other main solutions, the immersed tunnel and the cable-stayed bridge, share first position.

<u>Assessment – marine area</u>

The permanent and transboundary impacts of the cable-stayed bridge on the Baltic Sea water exchange (hydrography) and the permanent impacts on the internationally important factor of bird migration play a key role in the overall result. In comparison with the temporary impairments of the immersed and bored tunnels (loss of habitat, suspended matter and sedimentation), which impact the environmental factors/environmental sub-factors water quality, planktic fauna, benthic fauna, benthic flora and fish, the permanent impairments of the bridge are more serious. They are the ultimate reason why, in the assessment of all environmental impacts across the different environmental factors, the cable-stayed bridge is placed in position 3 in the marine area.

In a direct comparison of the immersed and bored tunnel solutions, the advantages lie with the bored tunnel. Since the bored tunnel solution eliminates the need to excavate a trench on the sea bed, the adverse impacts of the construction process on marine life are tangibly reduced. The bored tunnel solution is therefore ranked first for the marine area, and the immersed tunnel second.

<u>Assessment – Lolland onshore area</u>

The result of the Danish Environmental Impact Assessment report (VVM) is clear. It states that the cable-stayed bridge is either the most favourable solution or at least equivalent to the immersed and bored tunnel solutions with regard to all environmental considerations. This assessment is based mainly on the fact that the construction takes less time and the construction site is smaller, thus significantly reducing the impairments on the coastal landscape. In a direct comparison of the immersed and bored tunnel solutions, the advantages are thought to lie with the bored tunnel (position 2). Although it takes longer to build than the immersed tunnel, the greater size of the construction site for the immersed tunnel – caused primarily by the need to assemble the tunnel elements in the coastal area – is considered to be more problematic (position 3).

<u>Overall classification for environmental impact</u>

The impacts of the main solutions often differ only slightly. The overall classification also has to take into account the fact that the section of the alignment located in the marine area is approximately twice as long as the sections on Fehmarn and Lolland combined. In some cases, the individual environmental impacts in the marine area (especially with regard to hydrography and bird migration) are much more far-reaching than the impact of the onshore sections. The impacts on the marine area therefore have greater weight in the overall assessment of the project's environmental impact than the impact on the mostly agricultural onshore areas. The rankings in the three assessment areas and the overall classification are shown in Tab. 3.5.

Tab. 3.5: Classification in relation to environmental impact

Assessment area	**Ranking of the main solutions**		
	Immersed tunnel	**Bored tunnel**	**Cable-stayed bridge**
Fehmarn onshore	1	3	1
Marine area	2	1	3
Lolland onshore	3	2	1
Overall position	**2**	**1**	**3**

The factors listed above lead to the conclusion that, despite its favourable ranking for the onshore areas on Fehmarn and Lolland, the cable-stayed bridge is the least suitable solution overall from an environmental perspective. The permanent and transboundary adverse impacts of the cable-stayed bridge on the Baltic Sea water exchange (hydrography) and the permanent negative impacts on the internationally important factor of bird migration play a particularly important role in this classification.

The immersed tunnel has a better ranking on Fehmarn than the bored tunnel. However, the differences are only slight and in some cases relate only to the period of construction. In the marine area and on Lolland, it is the bored tunnel which receives a more favourable assessment. The differences between the impacts of the two main solutions on Lolland are greater than the rankings imply. The construction site needed to assemble the tunnel elements has a particularly serious impact on the Syltholm wind farm. Taken together, the negative impacts of the immersed tunnel on Lolland outweigh its advantages on Fehmarn. As the immersed tunnel solution is also judged less favourably in the marine area, the overall advantages lie with the bored tunnel solution, which was therefore ranked first in the environmental impact assessment area. Second place goes to the immersed tunnel solution.

3.6.5.3. Assessment area regional planning

The regional planning assessment focuses on the criteria of 'accessibility' and 'economic stimuli'.

As all three main solutions are very similar in terms of their alignments and have the same connection points with the secondary rail and road networks, their regional planning impacts are identical – they all bring about equivalent improvements in the current situation. For this reason, all three main solutions are ranked in first position.

Tab. 3.6: Classification in relation to regional planning

	Immersed tunnel	Bored tunnel	Cable-stayed bridge
Overall position	**1**	**1**	**1**

3.6.5.4. Assessment area transport

The criteria 'transport efficiency of the Fehmarnbelt Fixed Link', 'transport safety in connection with the Fehmarnbelt Fixed Link' and 'navigational safety in relation to the Fehmarnbelt Fixed Link' are assessed in the assessment area transport.

The transport efficiency of the three main solutions depends on their integration into the network. This is practically identical for all three main solutions, i.e. the transport-related effects are the same and positive (including shortened travel times, resumption of railway freight traffic).

There are differences between the main solutions in terms of technical requirements and options for dealing with accidents. Both the immersed and the bored tunnel have 'safe areas' throughout, which is particularly important in the case of fire. The three main solutions meet all applicable safety standards, thus providing an extremely high level of safety and a good basis for efficient self-rescue and/or third-party rescue. In this respect, despite their different advantages and disadvantages, the three main solutions are classified as equivalent.

However, both tunnel solutions have a slight advantage over the bridge solution in terms of safety for motorised individual transport. Adverse weather effects that can reduce traffic safety, such as ice, fog, and heavy winds and rain, are not a factor in tunnels. The effect of the tunnels on navigational safety after the construction phase is neutral, i.e. neither positive nor negative. In the case of the cable-stayed bridge, on the other hand, there is a slight risk of ships colliding with the pylons and bridge piers. However, studies have shown that the chance of this happening is low. Ship collisions with bridges that would impact the traffic flow or entail significant repair costs are rare, and the risk of long-term effects on the traffic flow (more than three months) is extremely low.

The fact that the risk of ship collisions can be excluded and the immersed and bored tunnels are not dependent on the weather means that, in terms of transport, the immersed and bored tunnel solutions score somewhat better than the cable-stayed bridge. Since the immersed and bored tunnels do not differ significantly in this area, they are both ranked in first position.

Tab. 3.7: Classification in relation to transport

	Immersed tunnel	Bored tunnel	Cable-stayed bridge
Overall position	**1**	**1**	**3**

3.6.5.5. Assessment area urban development

This assessment area focuses on the criteria 'separation of built-up areas' and 'limitations to the development potential of built-up areas'. It does not take into account visual and transport-related impairments caused by the transportation facilities as these factors are included in the environmental assessment (environmental factors people and landscape, cf. EIA report, Annex 15 to the plan approval documents).

All three solutions are very similar in terms of their alignments, connection points with the secondary network and proximity to settlement areas. Bundling the new roads with the existing main transport axis on Fehmarn already minimises the negative impact on urban development. Furthermore, on both Fehmarn and Lolland the FBFL will mainly pass through agricultural zones and will not come into direct contact with built-up areas. Only a small number of farms on Lolland will be affected. Transport-links bisected by the main solutions will be restored, on both Fehmarn and Lolland. No built-up areas will be separated as a result of the project, and the development potential of built-up areas will not be limited. There will be no negative effects on urban development on either Fehmarn or Lolland.

None of the main solutions have significant, permanently different impacts under both criteria, either on Fehmarn or Lolland. The main solutions are therefore classified as equivalent in relation to urban development.

Tab. 3.8: Classification in relation to urban development

	Immersed tunnel	Bored tunnel	Cable-stayed bridge
Overall position	**1**	**1**	**1**

3.6.5.6. Assessment area agricultural structure

The assessment area agricultural structure focuses on structure and construction-related losses of agricultural land.

All three solutions pass through agricultural land on Fehmarn and Lolland. As the alignments of the three main solutions are virtually identical, the effects on the agricultural structures differ only slightly. In this area, the bored tunnel is a somewhat less favourable solution. As three tunnels are required for the road and rail sections and they descend underground at an earlier point, this solution takes up more agricultural land. There are minor differences between the immersed tunnel and the bridge in terms of the use of agricultural land in the transition to the link structure, but these are not relevant to the assessment.

The construction sites of all three main solutions take up a considerable amount of space. In the case of the immersed tunnel and the cable-stayed bridge, the majority of this space is located on the Danish side. On Lolland, the immersed tunnel elements are assembled in direct proximity to the coast. The bridge elements are manufactured in an existing factory in Denmark, thus reducing the area of the construction site. As with the immersed tunnel, the remaining area required is located in direct proximity to the coast. The tubing factory and separation plant required for the construction of the bored tunnel can also be located close to the coast. As a result, all three solutions have a similar, albeit only slightly negative impact on the agricultural structures on Lolland.

The situation on Fehmarn is different. The construction sites for the immersed tunnel and the cable-stayed bridge are located close to the coast and do not take up a great deal of agricultural land since the production facilities are located in Denmark. The bored tunnel, on the other hand, requires both a tubing production facility and a separation plant on Fehmarn. The construction site extends as far as Marienleuchte on land that is currently used for agricultural purposes. The area taken up by the construction site is many times greater than that of the immersed tunnel and cable-stayed bridge sites. During the construction period, lasting several years, these areas are no longer available for agricultural use.

The classification of the main solutions in the agricultural structure assessment area is determined mainly by the impact on Fehmarn. Since the construction takes up much more space and, what is more, lasts 1.5 years longer, the bored tunnel option is less suitable than the immersed tunnel and the cable-stayed bridge. There are no relevant differences between these two solutions.

Tab. 3.9: Classification in relation to agricultural structure

	Immersed tunnel	Bored tunnel	Cable-stayed bridge
Overall position	**1**	**3**	**1**

3.6.5.7. Assessment area FBFL construction method

The technical suitability of the construction methods is assessed according to the criteria 'technical risk' and 'reuse and transportation of excavated material'.

The three construction methods for the immersed and bored tunnels and the cable-stayed bridge are well-established and very frequently used techniques in the traffic infrastructure sector. They are described in Annex 18, Section 3.5 ‘Selecting suitable structural systems’. The special challenges of constructing the FBFL lie in the considerable length of the crossing and the complex geology of the Fehmarnbelt. The difficulties and risks caused by this are described in detail in Annex 18, Sections 6.7.2 (Immersed tunnel), 6.7.3 (Bored tunnel) and 6.7.4 (Cable-stayed bridge) describe and evaluate the difficulties and risks in detail, so this section only contains a summary of the most important results.

As it runs deeper underground, the bored tunnel is approximately 3.6 km (rail) and 2 km (road) longer than the cable-stayed bridge and the immersed tunnel. This significant additional length alone increases the risk of technical failures and delays in the construction of the bored tunnel compared with the immersed tunnel and the cable-stayed bridge. A further important consideration is that maintenance and repairs of the tunnel boring machines (TBM) have to be carried out underground. Due to the longer construction period, maintenance work has to be performed more frequently and is considerably more complex than for the freely accessible machines which are used for the construction of the immersed tunnel and the cable-stayed bridge.

The first step in building the immersed tunnel is to excavate a trench on the seabed. Having been prefabricated in a dry dock on land, the tunnel elements are then lowered into this trench and connected together. The complex seabed geology can cause problems with the trench excavation and the installation of the piers for the cable-stayed bridge. However, these difficulties are less problematic than for the construction of the bored tunnel, because the trenches, despite being underwater, are accessible from above. The construction site for the bored tunnel is not freely accessible in a comparable way. In the case of the bored tunnel, the great variety in the soil conditions poses a further significant risk. Among other things, there is a risk of encountering large rocks/boulders in an unstable environment. In such a scenario, grinding up and removing the rocks/boulders is very difficult and costly due to the unstable conditions. In addition, the highly abrasive effect of the soil necessitates frequent maintenance of the tunnel boring machines' cutting wheels. Not least due to the high pressure of up to 6 bar, this maintenance work is very costly and can only be performed by specialists.

Another factor is that the six tunnel-boring machines need to be designed and manufactured from scratch. Their inner diameter alone, which in the case of the rail tunnel is 15.2 m, creates special technical requirements for the design and construction of the tunnel-boring machines. This can result in delays, cost increases and other uncertainties for the entire project.

Particularly challenging aspects of the cable-stayed bridge are the pier construction and above all the very wide span of the main bridge. The process of lifting the prefabricated 200-m-long bridge elements poses a considerable technical risk. They weigh about 8,000 t and have to be lifted to an altitude of up to 70 m above sea level and assembled there. The required lifting tools are yet to be developed.

In the case of the immersed tunnel, the size of the tunnel elements poses challenges for the process of transportation (floating), as does the degree of accuracy required when positioning and immersing these elements. This process is also a risky one. However, as considerable experience has been gained in the use of this construction method in other tunnel projects, the risks associated with it are deemed to be more manageable than those of the two other construction methods.

The material excavated for the bored tunnel is mixed with the support and transport suspension used for the excavation. Though not posing a technical risk, this is nevertheless a disadvantage as the excavated material has to be separated from the support and transport suspension in order to be reused as intended. To do this, the material first has to be transported through the completed tunnel section to the separation plant, where it undergoes a complex separation process before being transported back to the reintegration site. More than half of the material processed on Fehmarn is reintegrated on Lolland. It has to be loaded onto ships for transportation. In contrast to this very complicated process, the transportation of excavated material from the immersed tunnel and the cable-stayed bridge is considerably easier. The excavated material is loaded onto barges directly at the excavation site and transported to the reintegration site.

The bored tunnel involves the greatest technical risks and the most complicated material transportation process. From a technical and procedural perspective, it is rated as much less favourable than the immersed tunnel and the cable-stayed bridge options. Due to the need to assemble the bridge elements at great heights, the costly pier foundation process and the very wide span of the main bridge, the cable-stayed bridge entails greater technical risks than the immersed tunnel. The immersed tunnel is therefore classified as more suitable than the cable-stayed bridge in the assessment area construction method.

Tab. 3.10: Classification in relation to construction method

	Immersed tunnel	Bored tunnel	Cable-stayed bridge
Overall position	**1**	**3**	**2**

3.6.5.8. Assessment area costs/profitability

The assessment area costs/profitability looks at both the investment costs and the running costs for operation, maintenance and repair. The structure's profitability is directly proportionate to the costs; the lower the total cost, the more profitable the project will be.

Detailed draft plans were drawn up for all three main solutions including the necessary technical equipment and connection points in the secondary network. These planning documents enable reliable cost calculations for the different options. The construction costs are explained in more detail in Annex 18, Section 6.8 ‘Costs/profitability assessment area’ and broken down according to the main groups of the ‘Instructions for calculating the costs of road construction projects (AKS 85)’. Main group 8 includes the costs for compensatory and replacement measures. The calculated operation and maintenance costs are based on experience from the construction of existing infrastructure. Tab. 3.11 contains a summary of the costs of the main solutions.

Tab. 3.11: Comparison of the costs of the main solutions (price basis: 2016)

Cost portion	**Costs in EUR million of the main solutions (immersed tunnel = 100)**		
	Immersed tunnel	**Bored tunnel**	**Cable-stayed bridge**
Investment costs	6,075	8,273 (+ 36%)	6,160 (+ 1%)
Operation and maintenance costs over 30 years	2,211	2,727 (+ 23%)	1,815 (-18%)
Total cost over 30 years	8,286	11,000 (+ 33%)	7,975 (-4%)

In terms of investment costs, the bored tunnel is by far the most expensive option, costing some 36% more than the immersed tunnel and the cable-stayed bridge. The main reasons for this are as follows: the six tunnel-boring machines have to be manufactured specially for this project. As the bored tunnel runs deeper underground than the immersed tunnel, it begins much earlier and ends later and therefore requires longer ramp and tunnel sections than the immersed tunnel and the cable-stayed bridge. A further key factor is that each of the three tunnel tubes requires its own comprehensive set of technical equipment and portal building. In the case of the immersed tunnel, one shared portal building is sufficient. Furthermore, the bored tunnel does not create any synergies, such as the parallel/overlaid road and rail alignments of the immersed tunnel and the cable-stayed bridge.

The investment costs of the immersed tunnel and the cable-stayed bridge differ by only EUR 85 million (approx. 1%). This very minor difference is not sufficient to reliably give the two solutions a different classification.

The annual operation and maintenance costs of the bored tunnel are significantly higher than those of the immersed tunnel and the cable-stayed bridge. Due to the three separate tunnel tubes, the bored tunnel requires more extensive technical installations, which in turn generate operating and maintenance costs. The costs of operating and maintaining the bored tunnel are some 23% higher than for the immersed tunnel and as much as 50% greater than those of the cable-stayed bridge. In a direct comparison of the maintenance costs of the cable-stayed bridge and the immersed tunnel, the advantages lie with the bridge solution. When the total costs shown in Tab. 3.11 are taken into consideration, however, these advantages are reduced.

The comparison between the immersed tunnel, bored tunnel and bridge technical solutions in the assessment area ‘costs/profitability’ shows that the bored tunnel should be given a significantly worse rating in terms of both investment and operating and maintenance costs than the immersed tunnel and the cable-stayed bridge. The differences in costs between the immersed tunnel and the cable-stayed bridge solutions are largely attributable to the varying operating and maintenance costs. They do not have the same weighting as the investment costs as they are considerably lower in absolute terms. The total cost advantage of the cable-stayed bridge solution is only 4%. In view of the higher technical risks of this main solution (see Section 3.6.5.7) and the associated potential increases in construction costs, the immersed tunnel and the cable-stayed bridge options are rated as equal from the perspective of costs and profitability.

Tab. 3.12: Classification in relation to cost

	Immersed tunnel	Bored tunnel	Cable-stayed bridge
Overall position	**1**	**3**	**1**

3.6.6. Summary evaluation of all assessment areas

The rankings for the assessment areas described above are listed in Tab. 3.13.

Tab. 3.13: Overview of the individual rankings

Assessment area	**Ranking of the main solution [-]**		
	Immersed tunnel	**Bored tunnel**	**Cable-stayed bridge**
Environmental impact	**2**	**1**	**3**
Regional planning	**1**	**1**	**1**
Traffic	**1**	**1**	**3**
Urban development	**1**	**1**	**1**
Agricultural structure	**1**	**3**	**1**
Construction method	**1**	**3**	**2**
Costs/profitability	**1**	**3**	**1**

The bored tunnel, with its comparatively minor impact on marine life, is the most favourable solution in terms of overall environmental impact, followed by the immersed tunnel. The cable-stayed bridge is classified as the least favourable option in this category, in part due to its hydrographic impact and its negative effects on bird and bat migration.

In the assessment areas regional planning and urban development, all three main solutions are given the same ranking. This means that both assessment areas are not relevant to the overall classification.

In the assessment area transport, the risk of a maritime vessel colliding with a bridge pier and the potential negative effects of the weather on the flow of traffic mean that the least favourable classification is given to the cable-stayed bridge. However, the difference between the bridge and the other two main solutions is only slight.

The difference between the immersed tunnel and the cable-stayed bridge in the agricultural structure assessment area is not decisive. The least suitable solution in this category is the bored tunnel, due to the greater use of area.

There are significant differences in the assessment areas construction method and costs/profitability. On account of the substantially higher risks of its construction methods and the 36% higher costs, the bored tunnel is classified as significantly less favourable than the two other main solutions. Due in part to the need to assemble very large prefabricated bridge components at great heights, the construction method for the cable-stayed bridge entails greater risks than that of the immersed tunnel. The immersed tunnel is therefore classified as more favourable than the cable-stayed bridge in the construction method assessment area. In the costs/profitability assessment area, there is no difference between the immersed tunnel and cable-stayed bridge options.

The impacts on the transport and agricultural structure assessment areas differ only slightly. Overall, however, the immersed tunnel is the most favourable solution, as it takes first position in both areas. The bored tunnel and the cable-stayed bridge options are both classified as less favourable solutions.

The key factors in the overall classification turn out to be the assessment areas environmental impact, construction method and costs/profitability, as the impact of the various solutions differs significantly in these areas. The bored tunnel's advantages in terms of environmental impact are offset by its considerable disadvantages in the construction method and costs/profitability assessment areas. These disadvantages outweigh the environmental advantages. This classification takes account of the fact that the immersed tunnel and the cable-stayed bridge are also viable from an environmental perspective. For these reasons, when all effects are taken into account, the bored tunnel is classified as the least suitable solution.

A direct comparison of the immersed tunnel and the cable-stayed bridge options does not reveal any relevant differences in the assessment areas regional planning, urban development, agricultural structure and costs/profitability. In all other assessment areas (environmental impact, transport and construction), the advantages lie with the immersed tunnel. All in all, the immersed tunnel is therefore classified as more favourable than the cable-stayed bridge. The final overall classification, following the evaluation of all main solutions in all assessment areas, is shown in Tab. 3.14.

Tab. 3.14: Overall evaluation

	Immersed tunnel	Bored tunnel	Cable-stayed bridge
Overall position	**1**	**3**	**2**

The option to be pursued is the immersed tunnel on the preferred alignment T – E – ME.

As part of the first plan amendment, new plans and updates and a concomitant general planning plausibility check were carried out (cf. Appendix 18, Section 6.9). In summary, these new plans and updates have not revealed any differences in the assessment areas of environmental impact, regional planning, transport, urban development. agricultural structure, building procedures and economic efficiency/ investment costs. Likewise, they have not revealed any changes to the overall assessment of the main variant analysis and have no impact on the selected alignment on the preferred route.