Cost-benefit analysis of The Fehmarn Belt Fixed Link

Report

The Danish Ministry of Transport

INCENTIVE

Contents

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1 Summary

The Fehmarn Belt Fixed Link is one of the largest standalone construction projects currently underway in Denmark. In the same way as the Great Belt Fixed Link and the Øresund Bridge significantly reduced travelling time and brought two regions and countries closer together, a Fehmarn Belt Fixed Link would bring Denmark and Scandinavia closer to Germany and the rest of Europe.

A quicker and easier way across the Fehmarn Belt

The tunnel under the Fehmarn Belt will reduce travelling time between eastern Denmark and the rest of Europe to the south. While it currently takes 45 minutes to cross the Belt by ferry, the journey will take ten minutes in a passenger car when the fixed link opens at the end of 2021. This in itself represents a significant time saving. However, no longer having to waste time waiting for the ferry or leave at a fixed time in order to reach a ferry departure will be equally important.

In this analysis we assume that the price to cross the Fehmarn Belt Fixed Link in a car or lorry will be similar to the ferry price. This means that travellers will enjoy all the benefits of arriving sooner without having to pay more than they do today.

Major upgrades of the railways will also provide benefits for travellers who are not crossing the border

The overall project comprises more than "just" a tunnel under the Fehmarn Belt. The infrastructure associated with the link will be upgraded in both Denmark and Germany. There will be some minor upgrades of roads, along with major upgrades of railways. In Denmark, the railway from Vordingborg to Rødby will be upgraded from single to double track. The upgrade will be implemented in parallel with the electrification of the railway from Ringsted to Rødby and the raising of the maximum speed to 200 km/h. The railway in Germany will be similarly upgraded between Lübeck and Puttgarden.

Once all the above measures, including upgrading of the German onshore facilities, have been completed, it will be possible to complete the train journey between Copenhagen and Hamburg in 2.5 hours. Furthermore, upgrading the Danish railway will result in a quicker train link for all commuters and other train passengers on South Zealand and between Lolland and Falster.

Large number of international travellers

The Fehmarn Belt Fixed Link is primarily an international link. One-third of the people expected to use the Fehmarn Belt Fixed Link will be resident in Denmark, the remaining two-thirds coming from abroad. Non-Danish travellers will be distributed relatively evenly between travellers passing through Denmark and travellers starting or ending their journey in Denmark.

Rail freight across the link will be even more international in nature. The traffic forecast for the Fehmarn Belt Fixed Link estimates that 90 per cent of rail freight traffic will consist of transit traffic to and from Sweden.

International travellers will enjoy all the benefits of the link, but will also have to pay for these.

The link will reduce the environmental and climate impacts of transport

The Fehmarn Belt Fixed Link will change traffic flows, most notably for rail freight traffic that currently uses the Great Belt. The route for this traffic will be shortened by 160 kilometres. This will result in less air pollution. At the same time, all other things remaining unchanged, trains and vehicles will use less energy making their own way across the Fehmarn Belt than a ferry plying the same relatively short

distance. However, the link will also encourage more people to travel, and consequently result in more air pollution and CO_2 emissions.

Despite this, in overall terms, the Fehmarn Belt Fixed Link will reduce air pollution and CO_2 emissions.

A benefit for Europe

The construction of the Fehmarn Belt Fixed Link and upgrading of onshore facilities represents a major investment. The analysis puts the construction costs for the link and onshore facilities in Denmark and Germany at BDKK 60. Despite this, the link will return a net benefit. Over 50 years, taking into account all costs and benefits in all affected countries, the Fehmarn Belt Fixed Link will return a user-funded net benefit of BDKK 26. This equates to an economic return of 5.0 per cent. Any project that achieves a return of more than 4 per cent is deemed to be a project that makes society richer.

The net benefit reflects time savings and greater flexibility in departure times for the various travellers using the link.

A benefit for Denmark and the Danish government

The link is also a benefit for Denmark in its own right. Taking into account all benefits and costs for Denmark alone, the link and the associated onshore facilities in Denmark will generate a net social benefit of BDKK 28 over 50 years. This equates to an economic return of 5.4 per cent.

Moreover, the fixed link also represents good business for the Danish state, once all impacts are considered. The tunnel and onshore facilities will be paid for by users who use the fixed link. The Danish Treasury will also benefit from a series of derived impacts. For example, revenues from the Great Belt and the Øresund links will be impacted, with fewer people using the Great Belt and more people driving to and from Sweden. The extra traffic will also generate revenues for the state in the form of vehicle tax. Finally, Denmark is expected to receive significant grants from the EU for the tunnel and the onshore facilities.

Thus, there will be a net benefit for users, the Danish government and society as a whole.

Sound investment

The cost-benefit analysis has been prepared based on the best knowledge currently available. However, uncertainty always attaches to estimates of returns on major infrastructure projects. We have therefore performed a number of sensitivity analyses highlighting the sensitivity of the result to various assumptions and calculations. The Fehmarn Belt Fixed Link is economically viable in all the sensitivity analyses.

In overall terms, the analyses also indicate that the Fehmarn Belt represents a sound investment for Europe and Danish society.

2 Overview

2.1 Introduction

The Danish Ministry of Transport has commissioned Incentive to evaluate the cost-benefit impacts of establishing a fixed link across the Fehmarn Belt, ahead of the presentation of the Danish Construction Act to the Danish Parliament (Folketing).

The results of the analysis are presented in this report. Throughout the report negative figures represent a cost and positive figures a benefit.

2.2 Results

Including all benefits and costs in all affected countries, the fixed link across the Fehmarn Belt generates an economic return of 5.0 per cent. This equates to an aggregate net benefit over 50 years with a present value of BDKK 26, cf. Table 1.

For all countries aggregate net benefits for users comes in at BDKK 39. Users will pay the lion's share of project costs; however, in net terms the state will incur a cost of BDKK -7. Furthermore, the link will generate benefits in the form of an improved environment and an augmented labour supply, along with a cost in the guise of reduced revenues from the ferries.

Computing the benefits and costs for Denmark alone results in an economic return of 5.4 per cent, and an aggregate net benefit over 50 years of BDKK 28.

In the following section we examine the individual elements of the cost-benefit analysis in detail.

Table 1: Cost-benefit results, BDKK (2014 prices, present value in 2014, market prices)

	Section	All countries	Denmark
The State	**4**	**-7**	**10**
Construction costs including residual value	4.1	-58	-53
EU support	4.1	0	10
Operations, maintenance and reinvestments	4.1	-20	-15
Revenues from user payments, fixed links	4.2	71	68
Train operators (passenger trains)	4.3	1	1
Taxes and tax corrections	4.4	-1	-1
Users	**5**	**39**	**15**
Road traffic - people	5.1	26	8
Road traffic - freight	5.1	5	2
Railways - people	5.2	8	5
Railways - freight	5.2	1	0
Other impacts	**6**	**-6**	**3**
External costs (environment, climate, noise, accidents)	6.1	2	1
Labour supply impact	6.2	1	2
Correction, earnings from ferries	6.3	-9	0
Total		**26**	**28**
Internal rate of return		**5.0%**	**5.4%**

Note: A negative sign indicates a cost.

Brief description of the difference between the financial and the cost-benefit analyses

A financial analysis only computes expenses and revenues for an individual stakeholder. A cost-benefit analysis computes all benefits and costs, i.e. it takes account of a number of other impacts. In the case of the Fehmarn Belt Fixed Link these include:

- construction costs not borne by Femern A/S or A/S Femern Landanlæg, e.g. the German onshore facilities.
- time benefits and driving costs for users.
- external impacts in the form of the environment, climate, noise and accidents.
- labour supply impacts.
- impacts on Scandlines A/S's earnings.
- impacts on the state's (or state-owned companies') revenues from, e.g., vehicle taxes, the Great Belt, Øresund, DSB, Rail Net Denmark and other taxes.

In a positive financial analysis users' payments exceed costs. However, it will not automatically follow that the fixed link will generate a positive economic return. This depends on the scope of the impacts that are not included in the financial analysis.

The updated financial analysis shows that the Fehmarn Belt Fixed Link has a payback period of 32 years with reserves of 13.6 per cent included in the construction cost estimate, and 37 years with reserves of 30 per cent, cf. Femern A/S (2014a).

The Fehmarn Belt Fixed Link is thus viable from the perspective of both the published financial analysis and this cost-benefit analysis.

2.3 Report structure

In Section 1 we provided a brief summary of the analysis. Following this overview, in Section 3 we describe the scenarios that we look at in more depth in the cost-benefit analysis. We also examine predicted changes with and without a fixed link as estimated in the traffic forecast presented by Femern A/S in November 2014.

In Sections 4, 5 and 6 we look more closely at the subcomponents of the analysis. Finally, in Section 7, we describe the sensitivity analyses and non-valued impacts.

3 Assumptions and traffic

3.1 Availability and assumptions

The analysis follows the guidelines for cost-benefit analyses developed by the Danish Ministry of Transport and the Danish Ministry of Finance[1]

We apply the official, recognised tools to calculate and quantify the cost-benefit impacts of the fixed link: Spreadsheet tool *TERESA* and key figure catalogue *Unit Prices in Transport Economics*[2].

Assumptions

We have summarised the key assumptions applied in the analysis in Table 2.

Table 2: Overview of key assumptions

Topic	Assumption
Calculation year and price level	2014
Discount rate	4 per cent for the first 35 years, then 3 per cent.
Net-tax factor	1.325
First full year of operation of fixed link	2022
Calculation period	50 years from opening, i.e. up to and including 2071

Note: Femern A/S expects the link to open at the end of 2021.

Geographical demarcation

We have prepared a cost-benefit analysis for two different geographical demarcations:

- All countries: Here, we include benefits and costs for all countries.
- Denmark: Here, we only include benefits and costs for Denmark.

As the Danish state will own the fixed link[3], we have included all costs of constructing and operating the fixed link under the Danish demarcation. Similarly, all ticket revenues are included under the Danish demarcation[4].

3.2 Scenarios

We compare two scenarios in the analysis: A basic scenario assuming continued ferry operation and a project scenario assuming a tunnel is established under the Fehmarn Belt (subsequently referred to as "fixed link").

[1]Finansministeriet (1999): Guidelines for preparation of cost-benefit impact assessments, Finansministeriet (2013) New and lower cost-benefit discount rate and Transportministeriet (2003): Manual for cost-benefit analysis.
[2] We have applied TERESA v. 3.03 and Unit Prices in Transport Economics v. 1.5.
[3] See www.femern.dk for a more detailed description of the project organisation.
[4] Excl. German VAT.

In the scenario with a fixed link, in accordance with normal practice we assume that ferry operations on the Rødby-Puttgarden route will cease. This is consistent with changes in ferry traffic across the Great Belt on the opening of the Great Belt link, and ferry traffic between Dragør and Limhamn when the Øresund Bridge opened.

A sensitivity analysis in Section 7 illustrates the consequences of continued ferry operations.

Accurately computing costs and benefits necessitates an examination of future infrastructure requirements without a fixed link, i.e. assuming continued ferry operation. We address this in Section 4.1.

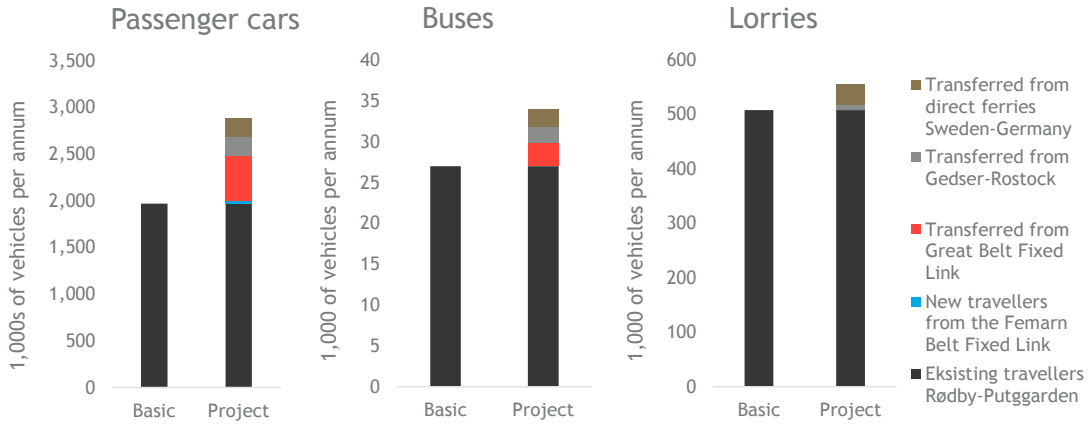
The traffic impacts described in Sections 3.3 and 3.4 are based on traffic data supplied by Femern A/S applying the FTC model, cf. Intraplan og BVU (2014) (referred to as "traffic forecast" in the remainder of the report). The traffic forecast is summarised in Femern A/S (2014b).

3.3 Road transport

Traffic in the opening year

The traffic forecast estimates that the establishment of a fixed link will result in an increase in traffic across the Fehmarn Belt in the opening year of 47 per cent for passenger cars, 26 per cent for buses and 9 per cent for lorries, cf. Figure 1. The majority of the increase in traffic is attributable to transfers from other routes. There is expected to be a transitional period in the first years following the opening, cf. figure 2.

Figure 1. Road traffic in the first full year of operation 2022 (1,000s of vehicles per annum)



Source: Femern A/S based on Intraplan og BVU (2014)

Traffic growth

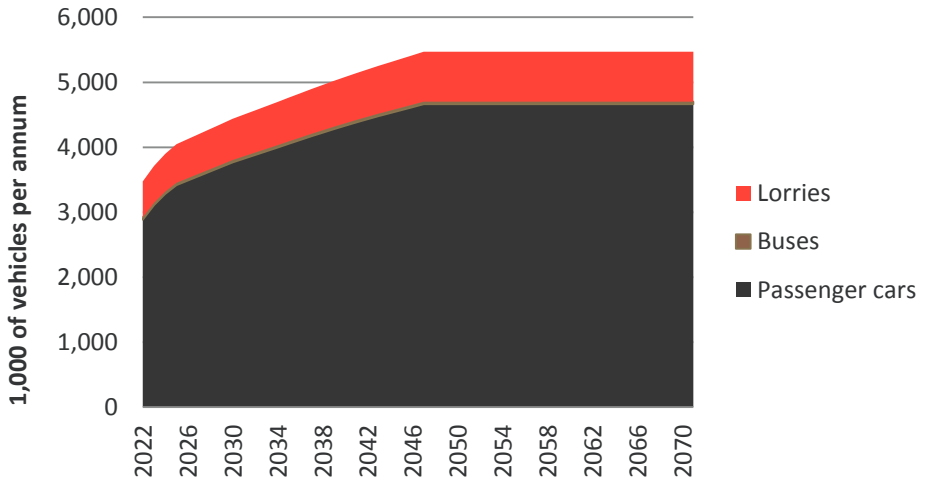
After opening, the number of passenger cars rises by an average of 1.9 per cent per annum until 2047 incl. the transitional period, cf. Table 3 and Figure 2. The comparable figures for buses and lorries are 0.6 per cent and 1.3 per cent respectively. The cost-benefit analysis does not include any traffic growth after 2047.

Table 3: Average annual growth, road traffic

Vehicles	2022-2047	2047-
Passenger cars	1.9%	0%
Buses	0.6%	0%
Lorries	1.3%	0%

Source: Femern A/S based on Intraplan og BVU (2014)

Figure 2. Changes in traffic with a fixed link



Source: Femern A/S based on Intraplan og BVU (2014)

The analysis is based on the assumption that percentage traffic growth will be the same in both the basic and the project scenarios. In other words, it is assumed that the fixed link across the Fehmarn Belt will not generate higher annual traffic growth following the opening and transitional period than if ferry operations were to continue. As uncertainty attaches to this assumption, we highlight the importance of the assumption for the result in a sensitivity analysis contained in Section 7.

Purpose of journeys

The overwhelming majority of journeys (excl. lorries) will be made by holiday traffic, cf. Table 4.

Table 4: Breakdown of journeys by purpose (excl. lorries)

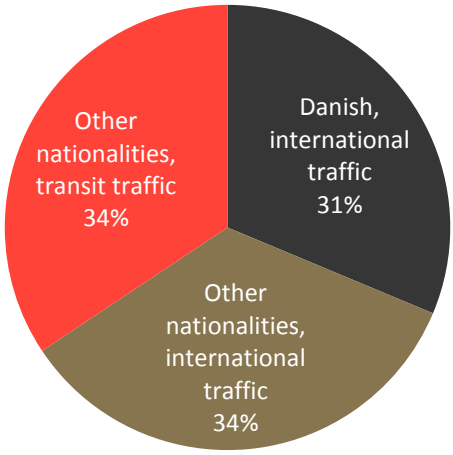
Purpose	2022-2047
Commuting	5%
Business	15%
Other (including holiday traffic)	80%
Total	**100%**

Source: Femern A/S based on Intraplan og BVU (2014)

Nationality

According to the traffic forecast, Danish residents will be responsible for 31 per cent of the road traffic on the Fehmarn Belt Fixed Link, cf. Figure 3. This is of importance to the result of the analysis for Denmark alone.

Figure 3. Breakdown of traffic by nationality and type



Source: Femern A/S based on Intraplan og BVU (2014)

3.4 Rail transport

Passenger traffic

According to the traffic forecast, the number of train passengers will rise from around 0.6 million per annum in the basic scenario to around 1.1 million passengers in the opening year once a fixed link has been established across the Fehmarn Belt. The increase is attributable to a pronounced reduction in travel time, and an increase in frequency from around 10 trains per day (both directions) to around 32 trains per day (both directions).

Subsequently, the traffic forecast assumes that the number of train passengers will decrease marginally until 2035 as a result of increased competition from cars.

For 2035-2047 we assume that the number of travellers will increase by 1 per cent per annum, cf. Table 5. No further passenger growth is included after this period.

Table 5: Average annual growth, rail passenger traffic

	2022-2035	2035-2047	2047-
Train passengers	-0.8%	1.0%	0%

Source: Growth 2022-2035 supplied by Femern A/S, growth for 2035-2047 is a calculation assumption.

Freight transport

The analysis for rail freight transport is similarly based on the traffic forecast.

According to the traffic forecast, 61 freight trains will cross the fixed link each day, 255 days a year in the first full opening year (both directions). This equates to around 16,000 freight trains per annum. Of these around 85 per cent will transfer from the Great Belt, cf. Table 6.

Table 6: Breakdown of rail freight transport

Breakdown	2022-2047
Great Belt	85%
Direct ferries Sweden-Germany	5%
New traffic	10%
Total	**100%**

Source: Femern A/S based on Intraplan og BVU (2014)

The traffic forecast estimates that 90 per cent of goods transport will be transit traffic, cf. Table 7.

Table 7: Breakdown of rail freight transport

Breakdown	Percentage
Transit	90%
International to/from Denmark	10%
Total	**100%**

Source: Femern A/S based on Intraplan og BVU (2014)

The traffic forecast estimates that the number of freight trains will increase by around 1.4 per cent per annum from 2022-2047, cf. table 8. No further growth in rail freight traffic is included after this period.

Table 8: Average annual growth, number of freight trains

	2022-2047	2047-
Rail freight	1.4%	0%

Source: Growth 2022-2047 supplied by Femern A/S based on Intraplan og BVU (2014); growth after 2047 is a calculation assumption.

Note: We have assumed an average weight of goods per freight train of 590 tonnes.

4 The State

4.1 Construction costs, EU grants and operations and reinvestments

Construction costs and EU grants

We have computed all costs that will be incurred in the basic scenario assuming continued ferry operation and in the project scenario with the fixed link. The difference between the costs in the project scenario and the basic scenario are included as additional costs on the establishment of the fixed link, cf. Table 9.

Femern A/S has notified the total construction costs to be applied in the analysis for coast-to-coast facilities as BDKK 49.4. Costs paid before 2015 are not included in the construction cost estimate. In addition, the construction cost estimate has been adjusted to include reserves of 30 per cent cf. the cost-benefit method.

Including all onshore facilities for "all countries", the total construction costs amount to BDKK 60.4.

The analysis for "Denmark" does not include costs for German onshore facilities. Here, the total construction costs therefore amount to BDKK 53.9. The EU is expected to award a grant of BDKK 8.7 for the Danish onshore facilities and the fixed link.

The EU grant is not included for "all countries", as with this geographical demarcation we are dealing with a reallocation between countries that are all included in the analysis.

Table 9: Construction costs and EU grants, BDKK (2014 prices, not discounted, factor prices)

	Basic	Project	Project - Basic
Fehmarn Belt Tunnel	0	-49.4	-49.4
Danish onshore facilities			
Electrification of the existing tracks and new Ringsted-Rødby	-4.1	-4.1	0
Speed upgrade to 160 km/h Vordingborg-Rødby	-1.1	-1.1	0
Double track and electrification etc. Vordingborg-Rødby	0	-2.7	-2.7
Speed upgrade from 160 km/h to 200 km/h Ringsted-Rødby	0	-1.0	-1.0
Preparatory work for freight trains	0	-0.3	-0.3
Great Belt Bridge (second track in "project")	-3.5	-4.1	-0.6
German onshore facilities			
Electrification and double track Puttgarden-Lübeck etc.	0	-8.3	-8.3
Upgrading to 4-lane road Heiligenhafen-Puttgarden	0	-0.7	-0.7
Electrification and double track Neumünster-Bad Oldesloe	-2.4	0	2.4
Total, "All countries"	**-11.2**	**-71.6**	**-60.4**
Total, "Denmark"	**-8.7**	**-62.6**	**-53.9**
EU grants. Only relevant for "Denmark"[2)]	**0**	**8.7**	**8.7**

Source: Rail Net Denmark, Femern A/S and the Danish Road Directorate.

Note: Construction costs paid before 2015 are not included.

Note: [1)] Electrification will necessitate raising the height of a number of existing bridges on the section etc.

Note: [2)] We have deducted Denmark's share of the contribution to the EU from the EU grant, cf. the standard cost-benefit method.

The above estimates for construction costs are based on the following assumptions:

- We have adjusted the construction cost estimate for coast-to-coast facilities to include reserves of 30 per cent. The reserves calculated here thus comply with the requirements of the Ministry of Transport's New Construction Budgeting principles, despite the fact that the Fehmarn Belt Fixed Link is not formally covered by New Construction Budgeting.
- The Danish onshore facilities are covered by New Construction Budgeting and therefore include reserves of 30 per cent.
- The budget for the German onshore facilities is based on publicly available figures. We have not made any corrections to these construction cost estimates.
- Without a fixed link it will be necessary to upgrade the railways in northern Germany between Neumünster and Bad Oldesloe in order to accommodate the future increase in freight traffic while maintaining the current level of service. This upgrade is not required in the project scenario, as with the fixed link freight traffic in Germany will instead use the upgraded railway section from Lübeck to Puttgarden.

The costs of the Danish onshore rail facilities in the project scenario include the following:

- Upgrading to double track between Vordingborg and Rødby.
- Electrification of the extra track between Vordingborg and Rødby.
- An extra track on the Storstrøm Bridge.
- Speed upgrade from 160 km/h to 200 km/h between Ringsted and Rødby.
- Preparatory work for freight trains, including noise barrier.

Operating costs and reinvestments

The total costs of operation and reinvestments comprise around BDKK 46 over 50 years, including all costs for "all countries", cf. Table 10. The analysis for "Denmark" does not include costs relating to the German onshore facilities. Costs are thus reduced to around BDKK 34.

Table 10: Operating costs and reinvestments, BDKK (2014 prices, not discounted, factor prices)

	All countries	Denmark
Fehmarn Belt Tunnel	-28.1	-28.1
Danish onshore facilities	-6.0	-6.0
German onshore facilities	-11.8	Not relevant
Total	**-45.9**	**-34.1**

Source: Femern A/S, Rail Net Denmark and the Danish Road Directorate.

Femern A/S has calculated the costs of the fixed link, and has also notified the breakdown of costs over the first 50 years of the fixed link's lifetime.

Operating and maintenance costs for the onshore facilities comprise 1 per cent of the construction costs per annum, while the reinvestments amount to 2 per cent per annum.

4.2 Revenue, fixed links

Ticket revenues from road traffic on the fixed link are calculated based on the traffic forecast as outlined in Section 3 and the ticket prices shown in Table 11.

Table 11: Assumed ticket prices, single ticket, DKK (2014 prices)

	Fixed link	Ferry
Passenger cars, average incl. VAT[1]	484	484
Buses, excl. VAT and discounts	2,033	2,033
Lorries, excluding VAT and discounts	1,989	1,989

Source: Femern A/S based on Intraplan og BVU (2014).

Note: [1] Incl. VAT for the fixed link. In practice VAT is not deducted from ferry tickets for passenger cars.

Femern A/S has notified an expected yield from rail charges. In 2022 this comprises MDKK 394 excluding VAT. The analysis also takes into account a decrease in the yield from the Great Belt Bridge, and an increase in the yield from the Øresund Bridge.

In aggregate, we calculate the total revenues from the fixed links at just under BDKK 71 over the first 50 years of the fixed link's lifetime (present value), cf. Table 12.

Table 12: Revenues, fixed links, BDKK (2014 prices, present value in 2014, market prices)

	All countries	Denmark
Road traffic	62.0	59.7
Fehmarn Belt	64.7	62.8
Great Belt	-3.6	-3.6
Øresund	0.9	0.4
Rail charges total	**8.7**	**8.7**
Total	**70.7**	**68.4**

Note: Yield includes VAT. For "Denmark" German VAT has been deducted from the Fehmarn Belt Fixed Link. Half of the change in ticket revenues for Øresund is included for "Denmark".

4.3 Operating costs for trains

The state's costs and revenues from operating passenger trains will change once the fixed link opens. Our calculations assume that passenger trains across the Fehmarn Belt will be operated by the public sector. This produces largely the same result as assuming that the traffic will be operated as "deregulated traffic" on market terms without state support.

Ticket revenues for the train operators are based on the valuation of the number of passenger trains per the traffic forecast, cf. Section 3.4, as well as on the assumption of an average ticket price of DKK 400 for a single journey on the Copenhagen-Hamburg section. This estimate is based on existing ticket types and prices.

The costs for the train operator comprise two components: operating costs and infrastructure charges. We have computed the change applying standard unit prices.

If there are more passengers, and thus more trains, this will increase costs. At the same time, costs will be reduced as a result of better utilisation of assets due to shorter journey time. Rail Net Denmark has notified how much of the saving in travel time with a fixed link is attributable to the onshore facilities

included in the project scenario, cf. Section 4.1. Based on the above, we have assumed an average time saving of an hour and a quarter between Copenhagen and Hamburg.

We have further calculated that the establishment of the fixed link and electrification of onshore facilities will make it possible to operate electric trains instead of diesel trains. This will generate a saving in procurement and operating costs of around 10 per cent.

In total, we calculate the aggregate net income for operators of passenger trains at around BDKK 1 over the first 50 years of the fixed link's lifetime (present value), cf. table 13.

Table 13: Operating costs, passenger trains, BDKK (2014 prices, present value in 2014, market prices)

	All countries	Denmark
Ticket revenues	4.7	2.3
Operating costs[1]	-1.3	-0.7
Infrastructure charges	-2.0	-1.0
Total	**1.4**	**0.7**

Note: For "Denmark" we have assumed that the benefits for the operator are equally distributed between a Danish and a German train operator.

Note: [1] includes the train operator's saved operating costs.

We have not included lower train operator costs due to investments in onshore facilities for local trains in Denmark and Germany that do not cross the Fehmarn Belt.

Since greater uncertainty attaches to the statement of the impacts for passenger trains than the other items in the analysis, we have prepared a sensitivity analysis showing the impacts of reduced rail passenger traffic (see Section 7).

Freight trains are currently exclusively operated by private operators. We include the benefits attributable to the above in Section 5.2.

4.4 Taxes and tax corrections

In accordance with normal practice for cost-benefit analyses, we have adjusted for direct and indirect impacts ("tax corrections") on the tax yield.

Certain assumptions need to be applied to calculate these corrections for the analysis for Danish geographical demarcation. We have calculated the impacts based on the following principles:

- The changes in km charges and tax corrections for km charges are estimated based on the location where the transport takes place.
- Tax corrections for user payments on the fixed link and ticket revenues for public transport are calculated based on the traveller's nationality.

In total, we calculate aggregate revenues from taxes and tax corrections at around -BDKK 1 over the first 50 years of the fixed link's lifetime (present value), cf. Table 14. This comprises increased state revenues from road traffic taxes, e.g. excise tax, due to increased traffic. At the same time, in overall terms users will pay more for bridge tolls and train tickets, which means that they will spend less money on other goods. As these other goods are subject to VAT and taxes, this will generate a loss for the government.

Table 14: Taxes and tax corrections, BDKK (2014 prices, present value in 2014, market prices)

	All countries	Denmark
Road traffic	1.9	0.3
User payments	-2.8	-1.1
External costs	0.0	0.0
Total	**-0.9**	**-0.9**

Note: Excl. VAT revenues for Denmark and Germany from the fixed link.

5 Users

5.1 Benefits for road traffic

Below we outline how we have calculated the benefits for road traffic. The benefits for new and transferring travellers have been calculated applying the "rule of half", in accordance with standard procedure under the cost-benefit method.

Time benefits for road, fixed link

The key benefit in establishing a fixed link will be an overall reduction in journey time of around one hour for passenger cars and slightly less for buses and lorries, cf. Table 15.

Table 15: Time consumption with a fixed link (tunnel) and with continued ferry operation, minutes per journey

	Tunnel		Ferry						Time
	Journey time[1]	Check-in	Sailing time	Check-in[2]	Hidden waiting time[3]	Waiting time[3]	Departure	Total	
Passenger cars	10	2	45	10	9	6	5	75	63
Buses	11	2	45	5	0	6	5	61	48
Lorries	14	2	45	5	9	6	5	70	54

Note: [1] Journey time in the tunnel is calculated based on permitted maximum speeds, and the fact that the tunnel is 19 km long. [2] The average is 15 min. for passenger cars; FLEX or Autobizz/EasyGo customers can check in 5 min. before departure. Source: http://www.scandlines.dk/kundeservice/check-in-i-havnen.aspx, 20 October 2014. [3] Calculated based on guidelines in Unit Prices in Transport Economics: "For time intervals of more than 12 min. waiting time is calculated as 6 min., while hidden waiting time is calculated as half of the interval less 6 min. (thus waiting time and hidden waiting time together comprise half of the time interval)". The value of less hidden waiting time is not included for buses, as significant uncertainty attaches to this.

In addition, passenger cars will save one minute of journey time following the upgrading of the German road link between Puttgarden and Heiligenhafen.

The statement of time consumption follows the cost-benefit method. The calculation takes account of the fact that the time value differs for individual components for the overall travel time, cf. Unit Prices in Transport Economics.

The traffic forecast assumes a driving speed of 70 km/h through the tunnel, which is lower than the actual expected speed, cf. Femern A/S (2014b). We have therefore prepared a sensitivity analysis using the same time consumption as in the traffic forecast (see Section 7).

However, a number of elements in the above table have no time values in Unit Prices in Transport Economics. We have valued these elements as follows:

- Hidden waiting time for lorries and passenger cars: In the analysis we have valued hidden waiting time for lorries and passenger cars at 80 per cent of the time value for journey time. The same conditions are applied for public transport in Unit Prices in Transport Economics.
- Waiting time for lorries and passenger cars: Valued as delay time. The same conditions are applied for public transport in Unit Prices in Transport Economics.

We estimate that the overall time benefits for road traffic will amount to BDKK 34 over the first 50 years of the fixed link's lifetime (present value), cf. Table 16. Just under a third of the benefits will accrue to Denmark.

Table 16: Time benefits for road traffic, BDKK (2014 prices, present value in 2014, market prices)

	All countries	Denmark
Passenger cars and buses[1]	28.1	8.8
Lorries	6.2	2.0
Total	**34.3**	**10.8**

Note: [1] Of which commuting comprises 2 per cent, business 41 per cent and other purposes, e.g. leisure, 57 per cent.

Driving costs by road

Users' driving costs will change once the fixed link has been established. We have calculated the overall impact on driving costs based on key figures from Unit Prices in Transport Economics and the overall change in the number of km driven – i.e. we have calculated the impact of existing travellers on the Rødby-Puttgarden route, and travellers who transfer from Gedser-Rostock and direct ferries between Sweden and Germany, facing longer drives in terms of distance travelled. Travellers who transfer from the Great Belt will have shorter drives.

In total we calculate the changes in driving costs as an extra cost of around -BDKK 3 over the first 50 years of the fixed link's lifetime (present value), cf. Table 17. For Denmark alone, the additional cost is BDKK -1.

Table 17: Driving costs, BDKK (2014 prices, present value in 2014, market prices)

	All countries	Denmark
Passenger cars and buses[1]	-2.2	-0.7
Lorries	-0.9	-0.3
Total	**-3.1**	**-1.0**

Note: For tourist buses we have applied an average driving cost, which in 2014 equated to DKK 347.

Note: [1] Of which commuting comprises 6 per cent, business 11 per cent and other purposes, e.g. leisure, 83 per cent.

Driving costs are not impacted by ticket prices in the analysis, as the prices of the fixed link are presumed to be the same as for the ferries.

5.2 Benefits for rail traffic

Below we provide a short description of how we have calculated benefits for train passengers and rail freight transport.

Rail passenger traffic

Rail passengers experience benefits in the form of reduced journey time due to the fixed link and the onshore facilities that are established as a result of the fixed link, cf. Table 1.

Rail Net Denmark has announced how much of the saving in travel time from the fixed link is attributable to onshore facilities associated with the fixed link, cf. Section 4.1. Based on the above, we have assumed an average time saving of an hour and a quarter between Copenhagen and Hamburg.

The average waiting time for international train passengers will be significantly reduced once the fixed link has been completed. In overall terms, the higher frequency will be responsible for 45 per cent of

time savings for international passengers, while the remaining 55 per cent will be due to saved journey time. For national travellers we have only included saved journey time.

We have assumed that the average ticket price remains unchanged. The benefit for these passengers therefore solely comprises saved time. In the case of the international travellers we have assumed that 50 per cent of the travellers will be resident in Denmark.

Table 18: Time benefits for rail passenger traffic, BDKK (2014 prices, present value in 2014, market prices)

	All countries	Denmark
International passengers	5.4	2.7
National travellers, Denmark	2.0	2.0
National travellers, Germany	0.2	0
Total	**7.6**	**4.7**

Rail freight

We have calculated the benefits for private rail operators that transport freight based on Unit Prices in Transport Economics.

The benefits comprise saved operating costs due to the fact that the distance travelled via the Fehmarn Belt is around 160 km shorter than via the Great Belt. On the other hand, the costs of using the Fehmarn Belt Fixed Link are higher than the saved infrastructure charges and payments to cross the Great Belt. There is an additional benefit in that the goods arrive more quickly. In valuing the saved journey time we have applied an average time value for rail freight of DKK 1.2 per hour per tonne based on Swedish studies, cf. Trafikverket (2014)[5].

This results in an overall benefit of around BDKK 1 for all countries, cf. Table 19. There is a minimal benefit for Denmark. This is due to the fact that 90 per cent of rail freight traffic flows between Sweden and Germany, cf. the traffic forecast, and an assumption that 50 per cent of benefits for international freight traffic to and from Denmark accrues to Denmark.

Table 19: Benefits for rail freight traffic, BDKK (2014 prices, present value in 2014, market prices)

	All countries	Denmark
Infrastructure charges	-3.6	-0.2
Operating costs	3.6	0.2
Time benefit, freight	0.6	0.0
Total	**0.6**	**0.0**

[5] Since 90 per cent of rail freight comprises transit traffic to Sweden, we believe that it is more appropriate to apply the Swedish time values.

6 Other impacts

6.1 External costs (environment, climate, noise and accidents)

The establishment of a fixed link impacts the external costs (environment, climate, noise and accidents) in three ways:

- The cessation of ferry operations will reduce environmental and climate impacts.
- Increased driving of passenger cars, lorries and buses will also increase the environmental and climate impact (cf. Section 5.1).
- Increased passenger and freight train traffic will also increase the environmental and climate impact.

In overall terms, the establishment of the fixed link reduces external costs equating to a gain of around BDKK 2 over the first 50 years of the fixed link's lifetime, cf. Table 20. The calculated benefit for Denmark alone is around BDKK 1.

Table 20: External costs, BDKK (2014 prices, present value in 2014, market prices)

	All countries	Denmark
Accidents	-1.0	-0.4
Noise	0.0	0.0
Air pollution	2.7	1.4
Climate	0.4	0.2
Total	**2.2**	**1.2**

We have calculated the average discharge of emissions per passenger car per ferry crossing, cf. table 21. These figures reflect the fact that the ferry's environmental impact will be reduced following the introduction of the SECA (Sulphur Emission Control Area) in the Baltic Sea. The external costs for road and rail have been calculated using unit prices for rural areas from Unit Prices in Transport Economics.

Uncertainty attaches to the calculation of environmental and climate impacts from the ferries. We have therefore performed two sensitivity analyses with respectively no, and half as many, environmental and climate impacts (see Section 7).

Table 21: Emission factors for Rødby-Puttgarden ferries (kg/passenger car/crossing)

CO_2	SO_2	NO_x	HC	CO	Particulates
20.63	0.01	0.38	0.02	0.04	0.01

Source: Incentive based onTransportministeriet (2010), www.scandlines.dk and MARPOL Annex VI Regulation 14.

6.2 Labour supply impact

In accordance with normal practice for cost-benefit analyses we have valued the impact on labour supply by computing the following two subcomponents:

- Labour supply distortion (previously called "tax distortion"). Calculated as 20 per cent of the net impact on the Danish Treasury.

+ Labour supply benefit: Calculated as 20 per cent of the user benefits for commuters and commercial transport.

The overall impact on labour supply is calculated as a benefit of around BDKK 1 over the first 50 years of the fixed link's lifetime (present value), cf. table 22. The calculated benefit for Denmark alone is around BDKK 2.

Table 22: Labour supply, BDKK (2014 prices, present value in 2014, market prices)

	All countries	Denmark
Labour supply distortion	-3.5	0.2
Labour supply benefit	4.3	1.6
Total	**0.8**	**1.8**

6.3 Correction to revenues from ferries

The analysis is based on the assumption that ferry operation on the Rødby-Puttgarden route will cease if a fixed link is established.

In the previous analysis, COWI (2004), it was assumed that ticket revenues on the Rødby-Puttgarden route would equal the costs of ferry operation - i.e. that a saving in ferry operations could be achieved equal to the ticket revenues from the ferries once the fixed link has been established.

Here, we have corrected for the possibility that operating costs (including a normal return on equity) are lower than ticket revenues from the route. All other things remaining unchanged, this correction reduces the net social benefit for the Fehmarn Belt Fixed Link.

We cannot accurately establish the size of the difference between costs and revenues on the Rødby-Puttgarden route based on publicly available material. Overarching publicly available accounting figures estimate the difference between revenues and costs at around 15 per cent of the costs. The main analysis applies this estimate.

As significant uncertainty attaches to this estimate, we have performed two sensitivity analyses highlighting the consequences for the result of alternative assumptions, cf. Section 7. More specifically, we have examined the consequences of an assumption of 0 per cent (equating to the assumptions in COWI, 2004), and of 30 per cent.

The impact is exclusively calculated for "all countries", as Scandlines is foreign-owned.

We have computed the overall impact at BDKK 9 over the first 50 years of the fixed link's lifetime (present value).

7 Sensitivity analyses and non-valued impacts

Sensitivity analyses

Significant uncertainty attaches to the estimates for a number of the elements of the cost-benefit analysis. We have therefore performed a number of sensitivity analyses illustrating the degree to which the result is dependent on the assumptions. The results of the sensitivity analyses can be viewed in table 23.

The establishment of the fixed link results in a social surplus in all the investigated sensitivity analyses - both including costs solely for Denmark and including costs for all countries.

Table 23: Results of sensitivity analyses, internal rate of return

	All countries	Denmark
Main analysis	**5.0%**	**5.4%**
Infrastructure		
1. Costs of tunnel and onshore facilities paid before 2015 included	4.7%	5.0%
2. +/- 10% for coast-coast facilities	4.7% / 5.4%	5.0% / 6.0%
3. +/- 10% for Danish onshore facilities	5.0% / 5.0%	5.4% / 5.5%
4. +/- 25% for German onshore facilities	4.9% / 5.1%	Not relevant
5. +/- BDKK 2 in EU support	Not relevant	5.6% / 5.2%
Traffic across the Fehmarn Belt		
6. Increase in traffic 2047-2071 is 1% (instead of 0%) for road and rail traffic	5.1%	5.5%
7. +/- 10% for traffic growth 2022-2047 for road and rail traffic	5.2% / 4.8%	5.6% / 5.3%
8. 25% traffic induction, road traffic[1]	4.6%	5.0%
9. 40% traffic induction, road traffic[1]	4.8%	5.2%
10. 25% traffic induction in 2022 for international rail passengers[2]	4.8%	5.3%
11. 40% traffic induction in 2022 for international rail passengers[2]	4.8%	5.3%
Other assumptions		
12. +/- 10% for traffic revenues on road section	5.1% / 5.0%	5.7% / 5.1%
13. Time usage, ferry and tunnel, as per traffic forecast	4.9%	5.4%
14. Excluding waiting time and hidden waiting time for road traffic	4.4%	5.2%
15. Climate and environmental impacts of ferries reduced by half	4.9%	5.4%
16. No climate or environmental impacts from ferries	4.9%	5.3%
17. No correction for earnings from ferries	5.4%	Not relevant
18. Double correction for earnings from ferries	4.6%	Not relevant
19. Hourly ferry operation after opening of the fixed link	4.1%	4.7%

Note: [1] The traffic induction in the financial analysis includes the transitional period. We have here applied the same interpretation.

In sensitivity analysis 19 we have assessed the impact of ferry operations continuing between Rødby and Puttgarden following the opening of the fixed link. Following the opening of the fixed link, the frequency of the ferries in the sensitivity analysis is reduced to once an hour and the ticket price of the ferries is reduced by 25 per cent. The traffic forecast estimates that this will result in 14 per cent fewer passenger cars on the fixed link in 2022, cf. Femern A/S (2014b). In the sensitivity analysis we assume that the disbenefit experienced as a result of a halving of the frequency will be offset by the lower ticket price for those travellers who continue to use the ferries. Similarly, we assume that the ferries'

costs will equate to their revenues when the frequency is reduced to hourly operation. The sensitivity analysis shows that even with continued ferry operation the Fehmarn Belt Fixed Link will be economically viable.

Non-valued impacts

The cost-benefit analysis reported here follows normal practice for cost-benefit analyses and the guidelines developed by the Danish Ministry of Finance and the Danish Ministry of Transport.

As always, some impacts are not valued in the cost-benefit analysis. We have summarised the most important of these in the table below.

As can be seen, we have, for example, not included the impact of the fixed link in relieving the pressure on the rest of the road and rail network (e.g. across the Great Belt). If we had included this impact, the result of the cost-benefit analysis would have been more favourable.

Similarly, we have not included the wider financial impacts of the Fehmarn Belt Fixed Link in the form of increased agglomeration and impacts on goods and service markets, as in accordance with normal practice these are not included in cost-benefit analyses. In the ex post cost-benefit analysis of the Great Belt Fixed Link we calculate these two impacts with major uncertainty at 17 per cent of the user benefits, cf. Incentive (2014).

Table 24: Non-valued impacts (selected examples)

Non-valued impact	Impact on result
1. Relieving of pressure on the rest of the road and rail network	↑
2. Disbenefits in the construction period	↓
3. Lower train operator costs internally in Denmark due to investments in onshore facilities	↑
4. Impact of travellers transferring from planes	?
5. Lower frequency of Gedser-Rostock and Sweden-Germany ferry routes	↓
6. Less air pollution and lower CO_2 emissions due to pt. 5.	↑
7. Regularity of the rail network	↑
8. Wider economic impacts	↑

The Fehmarn Belt Fixed Link also has other impacts, e.g. in the form of increased construction activities, which could have positive employment impacts over the short term. Such short-term economic impacts are not included in cost-benefit analyses, cf. Transportministeriet (2003).

8 References

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