Economic Evaluation of an improved Ferry System across the Fehmarn Belt

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On behalf of

Trafikministeriet, København

Bundesministerium für Verkehr, Bau- und Wohnungswesen, Berlin

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List of Annexes

0 Executive Summary

The economic and financial evaluation of a fixed link across the Fehmarn Belt finalised in June 1999 comprises the assessment of different technical solutions for a fixed link in comparison to the continued existence of the current ferry system. Following a series of discussions with parties involved, Danish MOT and German BMVBW decided to complement the study results with the evaluation of a scenario (additional with-case) which includes an improved ferry system across the Fehmarn Belt.

The technical and logistical outline of the additional scenario to be evaluated is based on information provided by Scandlines AG. The preferred variant focuses on a capacity extension of the current ferry system, employing a 5th ferry in 2010 and a 6th in 2020. The new ferries correspond to the 4 double-ended RO-RO ferries already in service. To reduce total travel time of passengers, in addition, the following combined measures are scheduled:

- Higher cruising speed of the ferries
- Reduction of ferries docking time in Rødby and Puttgarden
- Extension of see access channels (2 lanes)

As a result total transit time of passengers will be reduced from 62 minutes (current system with 4 ferries) to 54 minutes in 2010 and to 52 minutes in 2020 respectively.

Due to the limitations of funds and time it was decided not to elaborate a new traffic forecast. Therefore, the economic evaluation of an improved ferry system had to be based on traffic volumes derived from simplified assumptions to some extent. These assumptions are as follows:

- The improved ferry system allows a passage time for road vehicles which is very close to the time required in the 0+2 solution models. Hence it follows that the road traffic volumes forecasted for the 0+2 scenario can be adopted as a fair approximation for the improved ferry scenario assuming same fares charged and same road infrastructure hinterland investments as in the 0+2 case.
- With regard to railway freight traffic it was felt unrealistic to assume a re-routing from the fixed Great Belt link to Fehmarn Belt even with improved ferry services.

Hence it was decided not to consider investments in freight train ferries within the analysis.

- Likewise it was assessed that the considerable investments in rail hinterland infrastructure required to gain substantial time savings in rail passenger traffic will not be realised in the case of improved ferry services. Consequently, no investments in special passenger train ferries are considered. Thereby it is assumed that along with the improved ferry system passenger trains are carried on the same level of service as in the reference case.

Further to this basic framework, it is assumed that an improved ferry system will neither induce traffic shifts between the modes concerned nor change origin-destination patterns in road traffic as against the reference case. Following this, effects to be considered are route changes in road traffic plus new generated road passenger journeys.

To arrive at consistent traffic flow matrices for passenger cars, buses and trucks required for the evaluation, the best technical solution was found in combining the origin-destination flows forecasted for the reference case with the routes assigned in the 0+2 case. In a second step, new generated road passenger traffic forecasted for the 0+2 case is added to the matrices.

Methods and procedures employed for the evaluation of the improved ferry system across the Fehmarn Belt are in general the same as used for the evaluation of the fixed link alternatives. This refers to the calculation of relevant macroeconomic cost and benefits, basic decision criteria (NPV; CBR, IRR) as well as to sensitivity tests and risk analyses.

As far as the evaluation period is concerned, the average technical lifetime of relevant components (ferries, hinterland infrastructure, ports) sums up to 26 years. Accordingly, cash-flow tables have been calculated for the period from 2007 (first investments) to the year 2035 (first year of operation 2010 plus 26 years lifetime). The development of benefits in the period between 2010 and 2020 is assumed parallel to the time axis. For the years 2020 to 2035 annual benefits are set constant at their 2020 level.

The total sums of present values for each cost and benefit component are shown in the following table.

Table 0.1: Present values of cost and benefit components* (price level 1995)

Component	Million EURO
Investment cost	98.2
Maintenance and operation cost	- 10.1
Transportation cost	210.3
Time cost (value 1)	370.9
Time cost (value 2)	647.8
External cost	- 69.1
Consumer surplus	6.4
Regional employment effects	3.9
Sum of benefits (time value 1)	512.3
Sum of benefits (time value 2)	789.2
* discounted with 3%; positive values indicate positive benefits	

As can be seen from the above table, highest contribution to total benefits stem from reduced travel times and savings in transportation cost. Consumer surplus and regional economic effects are comparatively much less important. Negative benefits from increased external cost are first of all due to the higher CO_2-emissions of ferries operating on a higher cruising speed than in the reference case.

Macroeconomic decision criteria calculated from the cash-flow table as well as the results of sensitivity analyses carried out on the same line as for the fixed link solution models are shown in the following table.

Table 0.2 Evaluation results for the improved ferry system

	Time value 1	Time value 2
Basic evaluation		
Net Present Value (million EURO)	414	691
Benefit/Cost-Ratio (BCR)	5.22	8.04
Internal Rate of Return	34.8%	51.5%
Sensitivity Calculations		
BCR with discount rate 7%	3.77	5.83
BCR with investment cost + 20 %	4.35	6.70
BCR with investment cost – 20 %	6.52	10.05
BCR with increased traffic volumes	6.58	9.96
BCR with decreased traffic volumes	4.12	6.47
BCR with additional regional benefits	6.05	9.26

Comparing the evaluation results of the improved ferry system with the best ranked fixed link alternative, (immersed tunnel with two road lanes and one railway track plus reduced upgrading of hinterland infrastructure) the following conclusions can be drawn:

- Benefit/cost-ratios for the improved ferry system – 5.22 with the lower time value 1 and 8.04 with higher time value 2 – are substantially higher than for the 2+1 immersed tunnel scenario (1.85/2.5).
- Internal rates of return for the improved ferry system are even more superior than for the 2+1 immersed tunnel: Nearly 35% as against about 5.8% with lower time values and more than 50% against about 7.5% with higher time values.
- Net present values achieved by the improved ferry system, on the other hand, are rather small compared to the 2+1 immersed tunnel: about 400 million EURO as against 2.2 billion EURO with lower time values and just under 700 million EURO against about 4.0 billion EURO with higher time values.

Evaluation results show that the relative efficiency of the investment in an improved ferry system is considerably higher than for the 2+1 immersed tunnel, whereas the absolute magnitude of net benefits gained by the fixed link solution is by far not achievable by an improved ferry system.

1 Introduction

The economic and financial evaluation of a fixed link across the Fehmarn Belt finalised in June 1999 [PLANCO/COWI 1999] comprises the assessment of different technical solutions for a fixed link in comparison to the continued existence of the current ferry system. Following a series of discussions with parties involved, Danish MOT and German BMVBW decided to complement the study results with the evaluation of a scenario which includes an improved ferry system across the Fehmarn Belt.

Due to the limitations of funds and time it was agreed upon to consider the improved ferry system as an additional with-case in the year 2010 rather than as a modified reference case. The latter option would have implied to recalculate all technical solution models for the fixed link inclusive of the basic underlying traffic scenarios.

Again due to the mentioned restrictions it was decided not to elaborate a new traffic forecast. Therefore, the economic evaluation of an improved ferry system had to be based on traffic volumes derived from simplified assumptions to some extent.

Methods and procedures employed for the evaluation of the improved ferry system across the Fehmarn Belt are in general the same as used for the evaluation of the fixed link alternatives. This refers to the calculation of relevant macroeconomic cost and benefits, basic decision criteria (NPV; CBR, IRR) as well as to sensitivity tests and risk analyses.

2 Outline of the Improved Ferry System

The technical and logistical outline of the additional scenario to be evaluated is based on information provided by Scandlines AG[1]. The preferred variant focuses on a capacity extension of the current ferry system, employing a 5th ferry in 2010 and a 6th in 2020. The new ferries correspond to the 4 double-ended RO-RO ferries already in service. To reduce total travel time of passengers, in addition, the following combined measures are scheduled:

- Higher cruising speed of the ferries
- Reduction of ferries docking time in Rødby and Puttgarden
- Extension of see access channels (2 lanes)

[1] Working paper „Weiterentwickeltes Fährkonzept (Arbeitsstand 14.01.2000)“, submitted to the consultant by Scandlines AG

As a result total transit time of passengers will be reduced from 62 minutes (current system with 4 ferries) to 54 minutes in 2010 and to 52 minutes in 2020 respectively. The main features of the improved ferry system compared to the reference scenario (actual situation) are shown in the following table:

Table 1: Main features of the improved ferry system

Item	Dimension	Reference case	Improved ferry system	
			Year 2010	Year 2020
Number of ferries	-	4 (+1)	5	6
Transport capacity	pass. cars per hour or pass. cars plus trucks per hour	1072 440 + 112	1608 718 + 162	1930 861 + 194
Frequency of departures (from each port)	h^{-1}	2	3	3.6
Departures per day (from each port)	d^{-1}	48	72	86
Round trip time	min.	120	104	100
Time at docks	min.	16	11	9
Cruising time	min.	44	41	41
Average transit time of passengers	min.	44+16+2 = 62	41+11+2 = 54	41+9+2 = 52
Cruising speed of ferries	knots	16.5 – 18.5	18.5 – 19.5	18.5 – 19.5
Maximum cruising speed	knots	20	20	20

To achieve the scheduled reduction of ferries docking time in the ports, complementary measures in Rødby and Puttgarden (extension of prestorage areas, rebuilding and new gate/ticketing, traffic service system) are required.

3 Traffic Demand

As already noted, due to limitations of funds and time, it is not the task of this study to elaborate a new traffic forecast for the improved ferry scenario. However, to prepare the required basic traffic figures, the following assumptions were introduced:

- The improved ferry system allows a passage time for road vehicles (54 minutes in 2010 and 52 minutes in 2020 respectively) which comes close to the 0+2 solution models (55 minutes).[2] Hence it follows that the road traffic volumes forecasted for the 0+2 scenario can be adopted as a fair approximation for the improved ferry scenario assuming same fares charged as in the 0+2 scenario and same road infrastructure hinterland investments as in the 0+2 case.

- With regard to railway freight traffic it was felt unrealistic to assume a re-routing from the fixed Great Belt link to Fehmarn Belt even with improved ferry services. Hence it was decided not to consider investments in freight train ferries within the analysis.

- The considerable increase of rail passenger traffic in the 0+2 scenario compared to the reference case is induced by a serious reduction of travel time between Hamburg and Copenhagen from 3 h 50 min (via Fehmarn; 4 h via Great Belt) to 2 h 30 min. About 40 minutes of total time reduction stem from the construction of the fixed link (about 10 minutes passage time as against 50 minutes via ferry), the remaining 40 minutes from investments in the rail hinterland infrastructure. Compared to a fixed link, an improved passenger train ferry system could reduce total passage time rather marginally.

  Under these conditions it is assessed that the considerable investments in rail hinterland infrastructure required to gain substantial time savings in rail passenger traffic will not be realised in the case of improved ferry services. Consequently, no investments in special passenger train ferries are considered. Thereby it is assumed that along with the improved ferry system passenger trains are carried on the same level of service as in the reference case.

Further to this basic framework, it is assumed that an improved ferry system will neither induce traffic shifts between the modes concerned nor change origin-destination patterns in road traffic as against the reference case. Following this, effects to be considered are route changes in road traffic plus new generated road passenger journeys.

To arrive at consistent traffic flow matrices for passenger cars, buses and trucks required for the evaluation, the best technical solution was found in combining the origin-destination flows forecasted for the reference case with the routes assigned in

2 transit time 15 minutes; total access and egress time 40 minutes (source FTC)

the 0+2 case. In a second step, new generated road passenger traffic forecasted for the 0+2 case is added to the matrices.

Summarised results of the traffic assessment for the improved ferry scenario in the year 2010 are shown in the following table. More detailed tables by origin/destination and link as well as respective charts are provided in annex 1 (passengers) and annex 2 (freight) to this study.

Table 2: Road traffic volumes in the year 2010

Volumes of road traffic	Reference case		Improved ferry system	
(in 1,000)	Pass/tons	vehicles	pass/tons	Vehicles
	Scandinavia - Continent			
Road passenger traffic	14,013	3,918	14,203	3,988
Road freight traffic	28,229	2,448	28,229	2,448
	Via Fehmarn Belt			
Road passenger traffic	5,154	1,403	5,629	1,556
Road freight traffic	5,055	438	5,358	465

As can be seen, the improvement of the ferry system across Fehmarn Belt induces a slight increase of road passenger volumes between Scandinavia and the Continent by about 1.4% as compared to the reference case, whereas total freight traffic volumes remain unchanged.

Both route shifts and induced traffic result in an increase of traffic crossing the Fehmarn Belt by about 9.2% in passenger transport and 6% in freight transport. The share of Fehmarn Belt in total Baltic crossing road passenger traffic increases from 36.8% to 39.6%, i.e. by about 3%. Correspondingly, the market shares of competing ferry links decrease (Germany ↔ Sweden/Finland 1.1%, Germany ↔ Denmark 0.8%, Poland ↔ Denmark/Sweden 0.5%, other links 0.4%). In road freight traffic, the share of Fehmarn Belt increases by 1.1%., whereas the market share of direct ferry links Germany ↔ Sweden/Finland decreases by 0.6% (all other links together 0.5%).

Analogous to the evaluation of the fixed link alternatives, the economic evaluation of the improved ferry system considers traffic growth up to the year 2020. To extrapolate the given 2010 figures, the overall average annual market growth rates as predicted for the period 2010 – 2020 in [PLANCO/CWI 1999] for the reference case are used. The resulting traffic volumes crossing the Fehmarn Belt in the year 2020 are shown in the following table:

Table 3: Road traffic volumes crossing Fehmarn Belt in the year 2020

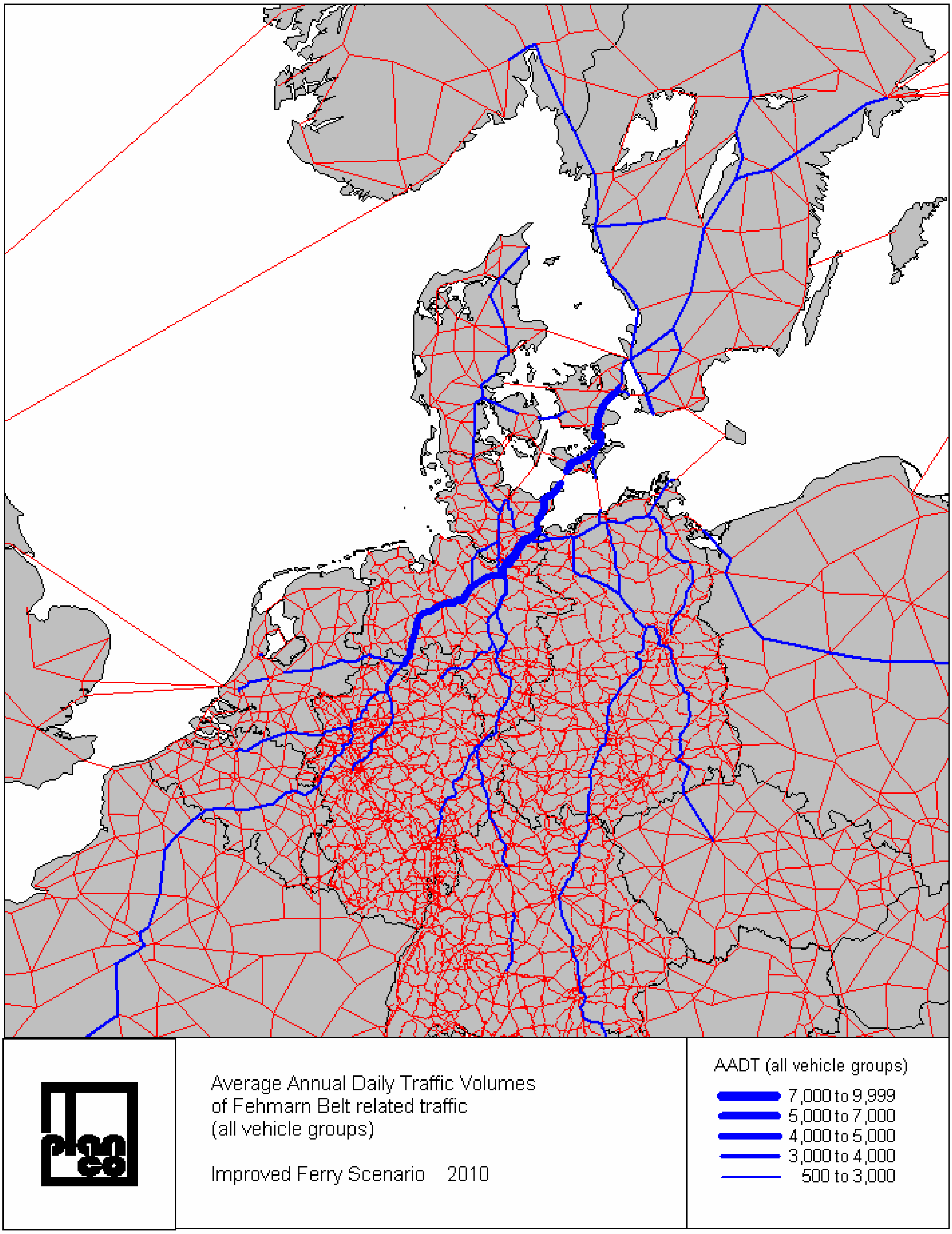
Volumes of road traffic (in 1,000)	Reference case		Improved ferry system	
	Pass/tons	Vehicles	pass/tons	Vehicles
	Via Fehmarn Belt			
Road passenger traffic	6,442	1,820	7,046	2,020
Road freight traffic	7,121	618	7,547	655

To consider the effects from the interaction between Fehmarn Belt related road traffic and other basic road traffic in the same way as for the fixed link alternatives, traffic volumes by origin/destination and route corridor forecasted for the improved ferry scenario are assigned to the specific sections of the road network using the travel time for each origin-destination flow as decisive parameter.

To come up with differentiated figures for normal weekdays, weekdays in holiday seasons and weekends required for the evaluation procedure, respective analytical data were obtained from traffic counts on the relevant sections of the road network.

A graphic illustration of average annual daily traffic volumes (AADT) on the relevant sections of the road network for the improved ferry scenario in the year 2010 is given in the following map. To ensure the readability of the map AADT less than 500 vehicles are not marked specifically.

Chart 1: AADT of Fehmarn Belt related road traffic (all vehicle groups) in the year 2010 – improved ferry scenario -



4 Calculation of Cost and Benefit Components

4.1 Investment cost

Investment cost to be considered in the improved ferry scenario include:

- Acquisition of 5th and 6th double-ended Ro-Ro ferry;
- Extension of sea access channels (2 lanes) in Rødby and Puttgarden;
- Complementary measures in the ports (extension of pre-storage areas, rebuilding and new gate/ticketing, traffic service system);
- Upgrading of the existing Danish two-lane motor traffic road between Ønslev and Sakskøbing (13.8 km) to motorway standard.

Based on information provided by Scandlines, investment cost for a double-ended Ro-Ro ferry similar to the ones in use already can be assessed with 48.92 million EURO (price level 1995).

Likewise origination from data prepared by Scandlines, estimated investment cost for the adaptation of port facilities sum up as follows:

Table 4: Investment cost port facilities (Million EURO; price level 1995)

Item	Puttgarden	Rødby	Total
Extension of see access (2 lanes)	5.93	6.91	12.84
Rebuilding and new gate and ticketing	1.29	1.29	2.57
Traffic service system	1.96	1.96	3.92
Extension of pre-storage area	10.74	10.74	21.48
Grand Total	19.92	20.90	40.81

Finally, the upgrading of the Danish motor traffic road requires investments of 13.88 million EURO (price level 1995).

Total investment cost for the realisation of the improved ferry system thus sum up to 152.53 million EURO (price level 1995).

Start of operation for the 5th and the 6th ferry is scheduled for the years 2010 and 2020 respectively. Accordingly, their acquisition is considered in the years 2009 and 2019.

Except for the extension of pre-storage areas, the adaptive measures in Puttgarden and Rødby are to be finalised with the start of operation of the 5th ferry (year 2010). We assume a construction period parallel to the upgrading of the Danish motor traffic road, i.e. 3 years from 2007 to 2009 with investments spend by 25%, 50% and 25% in the three construction years.

The extension of pre-storage areas for road vehicles in the ports is required with the start of operation of the 6th ferry, i.e. in the year 2020. Again we suppose a three years construction period (2017 – 2019) with investments spend by 25%, 50% and 25% during these years. The resulting cash flow of investment cost is shown in the following table.

Table 5: Cash flow of investment cost (Million EURO; price level 1995)

Year	Ferries	Ports	Road	Total
2007	-	4.83	2.78	7.61
2008	-	9.66	6.52	16.18
2009	48.92	4.83	4.58	58.33
2010	-	-	-	-
2011	-	-	-	-
2012	-	-	-	-
2013	-	-	-	-
2014	-	-	-	-
2015	-	-	-	-
1016	-	-	-	-
2017	-	5.37	-	5.37
2018	-	10.74	-	10.74
2019	48.92	5.37	-	54.29
Grand Total	97.84	40.81	13.88	152.53

Due to lack of information, the a. m. investment cost do not include the cost of compensation measures to balance impacts on nature and landscape which might be required due to the extension of see access and pre-storage areas. However, the effects of including such additional cost on the overall results of this study are expected to be low.

4.2 Maintenance and operation cost

Maintenance and operation cost of the new port facilities are calculated based on information provided by Scandlines whereas additional maintenance cost of the upgraded motor traffic road are based on standard cost rates used in the German FTIP. All cost values are again adjusted to the price level of the year 1995. The results of the calculations are shown in the following table.

Table 6: Maintenance and operation cost of new transport infrastructure (Million EURO; price level 1995)

Period	Ports	Road	Total
2010 – 2019	0.34	0.22	0.56
from 2020 onward	0.76	0.22	0.98

4.3 Transportation cost

Calculations carried out for the reference case and the improved ferry scenario cover transportation cost of passenger cars, busses, trucks and ferries. The assessments for road vehicles include both effects from changes of traffic routes and load dependent vehicle speed changes. Methods and data used correspond to the evaluation of the fixed link alternatives. Vehicle operation cost considered include time dependent standing cost, distance dependent basic running cost as well as speed dependent fuel cost. For the time span vehicles using ferries, only their time dependent cost are included.

Referring to ferries operation, contrary to the fixed link alternatives, the improved ferry system across Fehmarn Belt is characterised by higher operation cost than the ferry system in the reference case. Basic data required to calculate the changes of operation cost due to the improvement of the ferry system again have been provided by Scandlines. Cost items covered include personnel cost (wages, salaries, social security, a.s.o.), repair and maintenance, communication and data processing, sales cost and fuel consumption. Moreover, variable parts of overhead cost and additional expenditures for port operation are considered.

Depreciation of the new ferries, on the other hand, is not considered in the operation cost calculation, because the cost for their acquisition are already included in the investment cost of the improved ferry system. The results of the calculations are shown in the following table.

Table 7: Changes in transportation cost (Million EURO; price level 1995)

	Year 2010	Year 2020
Passenger cars	- 2.98	- 3.89
Busses	- 0.35	- 0.46
Trucks	- 8.06	- 10.46
Ferries Fehmarn Belt	7.73	5.89
Ferries other routes	- 7.12	- 9.43
Grand Total	- 10.78	- 18.36

As can be seen, the increase of operation cost for the improved ferry system across Fehmarn Belt is overcompensated by respective cost savings in road traffic and ferries operating on other routes. Referring to total sum of ferries operation cost alone, in 2010 there is a slight increase of about 0.6 million EURO compared to the reference case, whereas in the year 2020 even within the ferry sector transportation cost savings are realised (about 3.5 million EURO). Besides the higher volumes of traffic shifted from other routes to Fehmarn Belt in 2020 as against 2010, this is due to the effect that even underlying the current ferry system a capacity extension (5^{th} ferry) is required in 2020, reducing the cost–effectiveness of the current system compared to the improved ferry scenario.

4.4 Time cost

Analogous to the evaluation of fixed link alternatives, time cost changes in passenger traffic (except for drivers of busses) are valued separately as a specific benefit component. Again calculations include load dependent vehicle speed effects as well as route changes and ferry times. According to [PLANCO/COWI 1999] two alternative sets of time values are employed for the evaluation. The results are shown in the following table.

Table 8: Changes in time cost (Million EURO; price level 1995)

	Year 2010	Year 2020
Time Value 1		
Road passenger traffic	- 6.23	- 7.83
Ferries	- 17.82	- 22.64
Total	- 24.06	- 30.48
Time Value 2		
Road passenger traffic	- 10.87	- 13.65
Ferries	- 31.14	- 39.59
Total	- 42.00	- 53.24

About 75% of total time savings stem from reduction of travel times within the ferry sector, i.e. reduced transit times across Fehmarn Belt due to the improved ferry system plus effects from ferry route changes. Overall, the contribution of time cost savings to total benefits is considerably higher than that of transportation cost changes.

Positive values which might be attributed by some passengers (mainly lorry-drivers) to use time in the ferry system for compulsory breaks have not been considered in this study nor in the study on fixed link alternatives.

4.5 External cost

The calculation of external cost covers both the basic Fehmarn Belt traffic and new generated road passenger traffic. Components considered include emissions of poisonous exhaust gases and CO_2, traffic noise, traffic safety and separation effects from road traffic in build-up areas. The results of the assessment are shown in the following table.

Table 9: Changes in external cost (Million EURO; price level 1995)

Components	Year 2010	Year 2020
Poisonous exhaust gases	- 0.16	- 0.21
CO_2-emissions	4.55	4.29
Traffic noise	n. a.	n. a.
Traffic safety	- 0.64	- 0.85
Separation effects	- 0.02	0.01
Total	3.73	3.24
External cost of induced traffic	1.62	2.10
Grand total	5.35	5.35

As can be seen the improved ferry system induces slight cost reductions with regard to poisonous exhaust gases and traffic safety. Separation effects are neglectably low whereas relevant changes in road traffic noise (difference of more than 2 db (A)) could not be observed. However, positive effects are by far overcompensated by an increase of CO_2-emissions and additional external cost due to induced road passenger traffic. Details on the changes of CO_2-emissions are shown in the following table.

Table 10: Changes in CO_2-emissions (1,000 tons)

	Year 2010	Year 2020
Basic road traffic	- 10.28	- 13.44
Induced road traffic	7.18	9.32
Ferries	57.77	58.33
Total	54.67	54.21

The main effects are clearly due to the higher cruising speed of ferries crossing the Fehmarn Belt which in turn causes higher fuel consumption and CO_2-emissions. In road traffic, on the other hand, additional emissions of the induced traffic are more than compensated by a decrease in basic traffic.

4.6 Consumer surplus

In accordance with the evaluation of fixed link alternatives, consumer surplus of the induced road passenger journeys is assessed by 50% of the reduction of generalised cost of crossing the Fehmarn Belt, evaluated at market prices.

Total benefits sum up to 0.34 million EURO in 2010 and 0.56 million EURO in the year 2020. These benefits are clearly overcompensated by the additional external cost of induced road passenger traffic volumes.

4.7 Regional employment effects

Regional employment effects are considered both with regard to the construction of the new transport infrastructure and its operation.

The effects from construction are calculated using standard procedures and rates provided in the German FTIP-method. Benefits occur during the respective construction period only. Adjusted to the price level of the year 1995 total benefits during this period (2007 – 2009 and 2017 – 2019) sum up to 2.68 million EURO.

The assessment of regional employment effects from the operation of the improved ferry system can neither be based on a respective specific regional study (as was available for the fixed link scenarios) nor on standard procedures of the German FTIP-method (investments in ports are not covered there).

However, not to neglect this benefit component at all, a simplified approach is followed, assessing the effects proportional to the ones generated by the 0+2 fixed link solution model. The resulting annual benefits sum up to 0.16 million EURO in the period 2010 – 2019 and to 0.17 million EURO from the year 2020 onward.

It has to be noted that this assessment does not include the additional jobs created on the new ferries and in the ports of Rødby and Puttgarden which are of interest from the regional point of view but have to be omitted from the macroeconomic evaluation (shift of jobs from other activities and/or regions). Such effects have likewise not been included in the evaluation of the fixed link alternatives.

5 Evaluation results

5.1 Cash flow of cost and benefits

Based on the results of the calculations for the individual cost and benefit components described in the preceding chapters a cash flow table for the improved ferry scenario is calculated. In doing so, the development of benefits in the period from 2010 to 2020 is assumed parallel to the time axis. For the remaining years after the year 2020 up to the end of the evaluation period annual benefits are set constant at their 2020 level.

Corresponding to the average technical lifetime of relevant components (ferries, hinterland infrastructure, ports) the evaluation period of the improved ferry scenario is assessed with 26 years. Accordingly, the cash-flow table is calculated for the period from 2007 (first investments) to the year 2035 (first year of operation 2010 plus 26 years lifetime).

The computed cash flow is shown in the following table.

Table 11: Cash Flow table improved ferry scenario (Million EURO; price level 1995)

Year	Invest-ment	O+M cost	Transp. cost	Time cost I	Time cost II	External cost	Cons. Surplus	Employ-ment	Cash I	Cash II
2007	7.61							0.37	-7.23	-7.23
2008	16.18							0.79	-15.39	-15.39
2009	58.33							0.46	-57.87	-57.87
2010		-0.56	10.78	24.06	42.00	-5.35	0.34	0.16	29.43	47.38
2011		-0.56	11.54	24.70	43.13	-5.35	0.36	0.16	30.85	49.28
2012		-0.56	12.30	25.34	44.25	-5.35	0.39	0.16	32.27	51.18
2013		-0.56	13.06	25.98	45.37	-5.35	0.41	0.16	33.69	53.09
2014		-0.56	13.81	26.62	46.50	-5.35	0.43	0.16	35.11	54.99
2015		-0.56	14.57	27.27	47.62	-5.35	0.45	0.16	36.54	56.89
2016		-0.56	15.33	27.91	48.74	-5.35	0.47	0.16	37.96	58.79
2017	5.37	-0.56	16.08	28.55	49.87	-5.35	0.49	0.42	34.27	55.59
2018	10.74	-0.56	16.84	29.19	50.99	-5.35	0.51	0.68	30.59	52.39
2019	54.29	-0.56	17.60	29.83	52.12	-5.35	0.53	0.42	-11.81	10.47
2020		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2021		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2022		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2023		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2024		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2025		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2026		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2027		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2028		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2029		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2030		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2031		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2032		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2033		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2034		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
2035		-0.98	18.36	30.48	53.24	-5.35	0.56	0.17	43.22	65.99
Total	152.53	-21.31	435.59	757.05	1,322.41	-139.07	13.27	6.95	899.97	1,465.33

To calculate present values for the individual cost and benefit components according to their actual year of occurrence, they are discounted to a common base year. In accordance with the German FTIP the discount rate is set at 3%. Common base year for the discounting is 1998.

Table 12: Present values of cost and benefit components* (price level 1995)

Component	Million EURO
Investment cost	98.2
Maintenance and operation cost	- 10.1
Transportation cost	210.3
Time cost (value 1)	370.9
Time cost (value 2)	647.8
External cost	- 69.1
Consumer surplus	6.4
Regional employment effects	3.9
Sum of benefits (time value 1)	512.3
Sum of benefits (time value 2)	789.2
* discounted with 3%; positive values indicate positive benefits	

As can be seen from the above table, highest contribution to total benefits stem from reduced travel times and, with a distinct margin, savings in transportation cost. The share of time savings in total benefits (disregarding negative benefits from maintenance and external cost) ranges from 63% (time value 1) to about 75% (time value 2). The corresponding shares of transportation cost savings in total sum of positive benefits reach 36% (time value 1) and 24% (time value 2) respectively.

Consumer surplus and regional economic effects are comparatively much less important. Negative effects from increased external cost reduce total benefits by about 12% (time value 1) and by 9% (time value 2) respectively. They are first of all due to the higher CO_2-emissions of ferries operating on a higher cruising speed than in the reference case. The effect of higher maintenance cost of new transport infrastructure is comparatively much less significant (minus 1.9% and minus 1.3% respectively)

5.2 Net Present Values, Cost/Benefit Ratios and Internal Rates of Return

Macroeconomic decision criteria calculated for the improved ferry system include Net Present Value, Cost/Benefit Ratio and the Internal Rate of Return:

- The Net Present Value (NPV) gives the discounted value of aggregated annual balances of cost and benefits generated by the project during its lifetime;
- Benefit/Cost-Ratios (BCR) are calculated by dividing the total sum of (positive and negative) present values of benefits generated by the project by the present value of the investment cost;
- The Internal Rate of Return (IRR) measures that rate of interest at which the net balance of discounted annual inflows and outflows generated by the project becomes zero.

The results of the calculations are shown in the following table.

Table 13 Evaluation results for the improved ferry system

	Time value 1	Time value 2
Net Present Value (million EURO)	414	691
Benefit/Cost-Ratio	5.22	8.04
Internal Rate of Return	34.8%	51.5%

Results shown proof the macroeconomic efficiency of the improved ferry system evaluated. Even with the lower time values the BCR exceeds 5 with a corresponding IRR of nearly 35%. Underlying the higher time values results are even more impressive: The BCR reaches about 8 whereas the IRR exceeds 50%. With about 400 million EURO (time value 1) and nearly 700 million EURO (time value 2) the project achieves NPV of considerable magnitude also.

An assessment of these evaluation results compared to the fixed link alternatives is provided in the concluding chapter 5.4 of this report.

5.3 Sensitivity and risk analysis

Sensitivity analyses carried out follow the same line as for the fixed link solution models. They refer to the discount rate (5% and 7%), investment cost (± 20%) and traffic volumes (± 20% in passenger traffic and ± 40% in freight traffic). Moreover, the effects of including additional regional benefit components – as considered in the German FTIP-method – are analysed. The results of the calculations are shown in the following table.

Table 14 Results of sensitivity calculations

Benefit/Cost-Ratio	**Time value 1**	**Time value 2**
with a discount rate of 5%	4.41	6.80
with a discount rate of 7%	3.77	5.83
with investment cost + 20 %	4.35	6.70
with investment cost – 20 %	6.52	10.05
with increased traffic volumes	6.58	9.96
with decreased traffic volumes	4.12	6.47
with additional regional benefits	6.05	9.26

As can be seen evaluation results remain favourable even underlying more pessimistic assumptions than for the basic calculation. Comparatively lowest but still impressive BCR are achieved underlying a discount rate of 7% (3.77 with low time values; 5.83 with high time values) or assuming lower traffic volumes (BCR of 4.12 and 6.47 respectively).

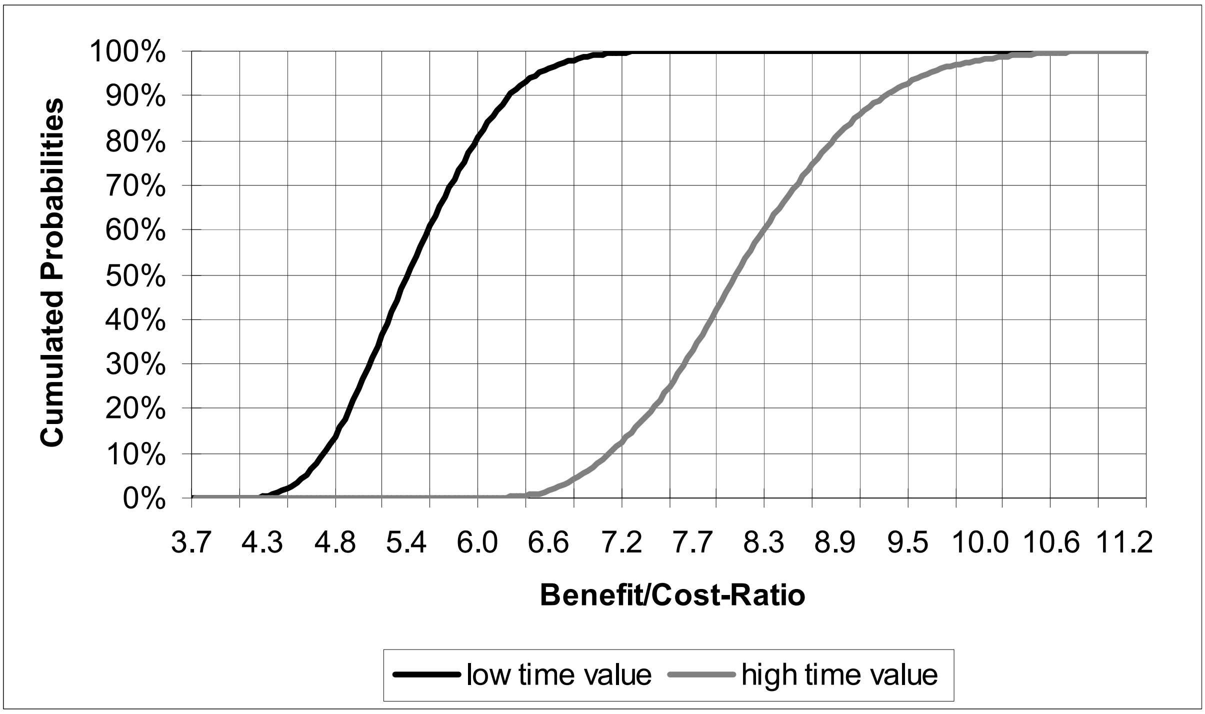
Employing more optimistic assumptions than for the basic calculations, highest BCR are reached in the cases with lower investment cost and higher traffic volumes (about 6.5 with low time values and about 10 with high time values).

Considering additional regional benefits like in the FTIP-method BCR increases from 5.2 to 6.1 (low time values) and from 8.0 to 9.3 (high time values) respectively.

To account for uncertainties regarding both the development of investment cost and forecasted traffic volumes within the ranges defined above, a combined risk analysis – computing probabilities based on monte carlo simulations for 2000 combinations – is carried out. For both traffic volumes and investment cost a normal distribution of probable values is assumed. However, to consider that initial investment cost calculations are more likely under- than overestimated, the most probable value is set at +5% of the original calculation.

Underlying the lower time values, BCR range from 3.7 to 7.4 with a mean value of 5.1. Within a 95% confidence interval, probable BCR range from 4.2 to 6.4. With regard to the higher time values, minimum, maximum and mean value read 5.7, 11.4 and 7.7 respectively. The 95% confidence interval of BCR ranges from 6.4 to 9.6.

Chart 2: Cumulated probabilities of Benefit/Cost-Ratios for the improved ferry system depending on variations of both investment cost and traffic volumes



5.4 Discussion of evaluation results

As shown in the preceding chapters, evaluation results achieved proof the macro-economic efficiency of the improved ferry scenario evaluated. Sensitivity tests and risk analyses provided moreover confirm the stability of evaluation results even under pessimistic assumptions.

The evaluation results of the improved ferry system compared to the fixed link alternatives are shown in the following table.

Table 15 Comparison of evaluation results

Solution model			Net Present Value (Million EURO; 3%)		Cost/Benefit-Ratio	
No.	Description	capacity	Time value 1	time value 2	time value 1	time value 2
1	Bored Railway Tunnel	0+2	-2,111	-775	0.42	0.79
2	Immersed Railway Tunnel	0+2	-2,138	-768	0.42	0.79
3	Cable Stayed Bridge	4+2	787	2,514	1.22	1.72
3.1	Suspension Bridge	4+2	348	2,086	1.09	1.53
4	Bored Tunnel	4+2	192	1,980	1.04	1.44
5	Immersed Tunnel	4+2	811	2,612	1.20	1.65
4.1	Bored Tunnel	2+1	2,111	3,828	1.76	2.38
5.1	Immersed Tunnel	2+1	2,232	3,973	1.85	2.50
Cable stayed bridge with reduced 2+1 hinterland infrastructure			1,674	3,362	1,50	2,01
Improved Ferry System			414	691	5.22	8.04

Comparing the results, the following conclusions can be drawn:

- Benefit/cost-ratios for the improved ferry system – 5.22 with the lower time value 1 and 8.04 with higher time value 2 – are substantially higher than for all fixed link alternatives including the best ranked immersed tunnel with reduced 2+1 improvement of hinterland infrastructure (1.85/2.50).

- Internal rates of return for the improved ferry system are even more superior than for the fixed link models. Compared to the best ranked 2+1 immersed tunnel they reach nearly 35% as against about 5.8% with lower time values and more than 50% against 7.5% with higher time values. These extraordinary high IRR are due to the fact that the discounted cumulated cash flow becomes positive already at the end of the year 2012, i.e. within 3 years after implementation of the improved system.
- Net present values achieved by the improved ferry system, on the other hand, are rather small compared to the 2+1 immersed tunnel: about 400 million EURO as against 2.2 billion EURO with lower time values and just under 700 million EURO against about 4.0 billion EURO with higher time values.

Evaluation results show that the relative efficiency of the investment in an improved ferry system is considerably higher than for the best ranked fixed link alternative, whereas the absolute magnitude of net benefits gained by the fixed link solution is by far not achievable by an improved ferry system.