



Concept Symposium 2016

Governing the Front-End of Major Projects

Financial uncertainty of the Fehmarn Belt fixed link



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The Fehmarn Belt fixed link project conditionally approved by the Danish parliament on 28 April 2015 is supposed to be built and commercially operated by a Danish state owned company and financed by loans guaranteed by the Danish government. The loans are going to be amortized by incomes from the tunnel users. According to original plans construction work was supposed to start by 2016 followed by tunnel inauguration in 2022 but this has been put on hold awaiting clarification of major uncertainty issues, such as lack of environmental approval by the German authorities. Never the less, contracts have been signed with major building consortia concerning tunnel works, implicating payment of stand-by fees until construction start-up and step-out fees in case of no German approval.

Since the official financial model is publically unavailable the uncertainty profiles presented in this paper are based on a financial model developed by the author covering 60 years of tunnel operation and validated in terms of project payback period within an absolute accuracy of ± 1 year compared to published results generated by the official model. Such features as length of construction period, construction costs and reserves, maintenance costs, subsidies by EU, road and rail traffic volumes and rates, inflation, nominal and real interest rates, depreciation, VAT, and joint taxation with Sund & Bælt Holding A/S are included. Uncertainty is represented and calculated by probabilistic uncertainty representation and Monte Carlo simulation as well as interval analysis. The resulting project uncertainty profiles are presented in terms of a traffic light metaphor: Green light corresponds to a payback period less than 40 years, yellow to 40-50 years, and red to larger than 50 years.

It turns out that the fixed link project constitutes a high risk business case and the likelihood of financial project failure in terms of the payback period being outside of the green light zone is substantially larger then acknowledged by the project proponents and presented to the public. This is primarily due to apparently too optimistic base case assumptions of critical, but uncertain, project variables and methodologically insufficient partial sensitivity analyses.

The presentation will also cover a number of actions taken by the Ministry of Transport and Building since the parliament's approval in attempts to justify initial project assumptions that have been seriously challenged by external criticism.

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Platform of the presenter: Neutral and independent analyst without preferences or sponsors

This presentation was completed by 15 August 2016

1. The Fehmarn Belt fixed link project



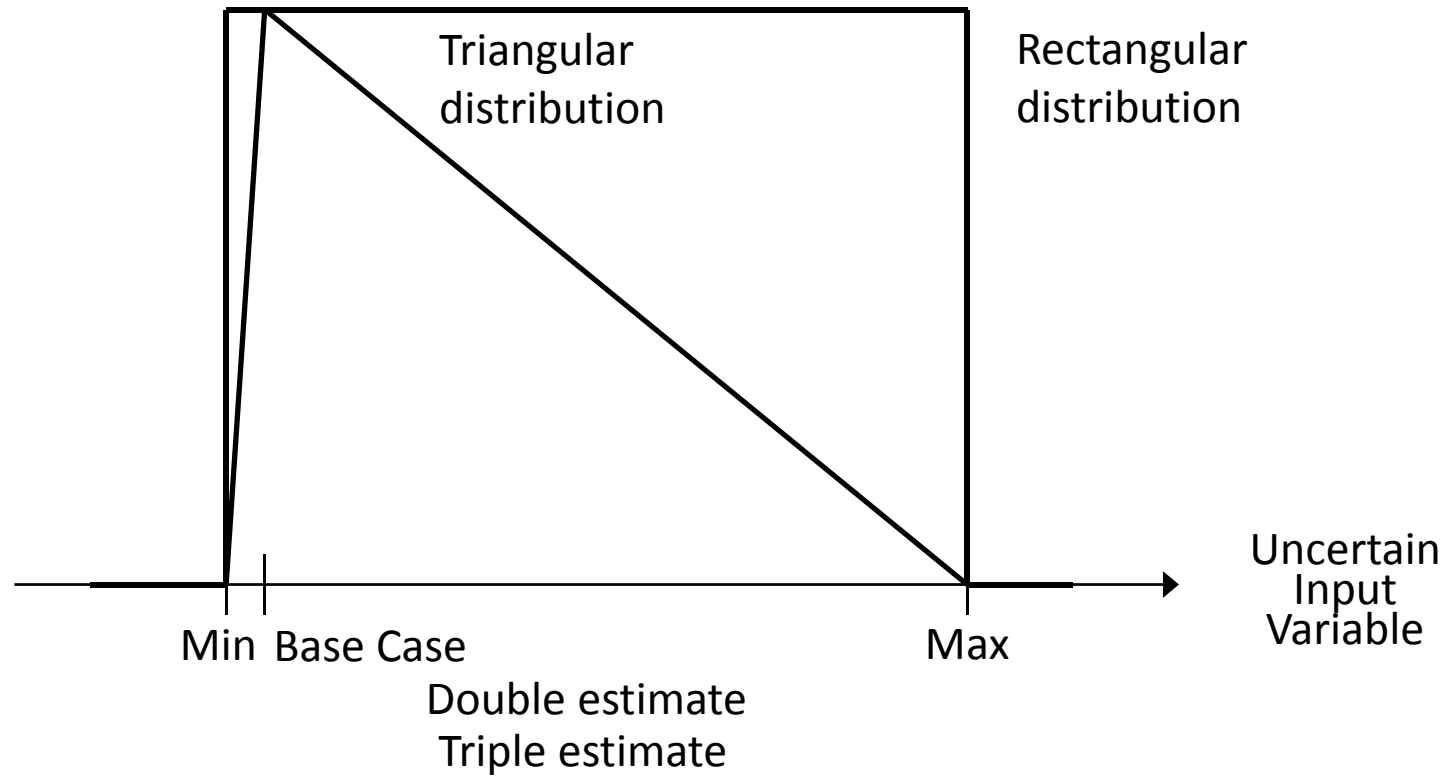
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2. On central estimates, partial sensitivities and uncertainty profiles

Partial sensitivity analysis vs. Uncertainty profile

Partial sensitivity analysis	Uncertainty profile
Input variable are changed one at a time	Input variables are changed simultaneously
Correlation and interdependencies of input variables can <i>not</i> be taken into account	Correlation and interdependencies of input variables can be taken into account
Amount of changes are arbitrary, but usually small	Amount of changes determined by actual uncertainty
Local analysis	Global analysis
Linear approximation applies	Linear approximation does not apply
May be calculated numerically or analytically by partial differentiation	Can not be calculated analytically. Instead use Monte Carlo simulation (aleatory uncertainty) or Interval analysis with global optimization (epistemic uncertainty)
Total uncertainty is under estimated	Correctly calculates total uncertainty

One-sided uncertainty of input variable



3. Uncertainty profiles of financial Base Cases 1 and 2

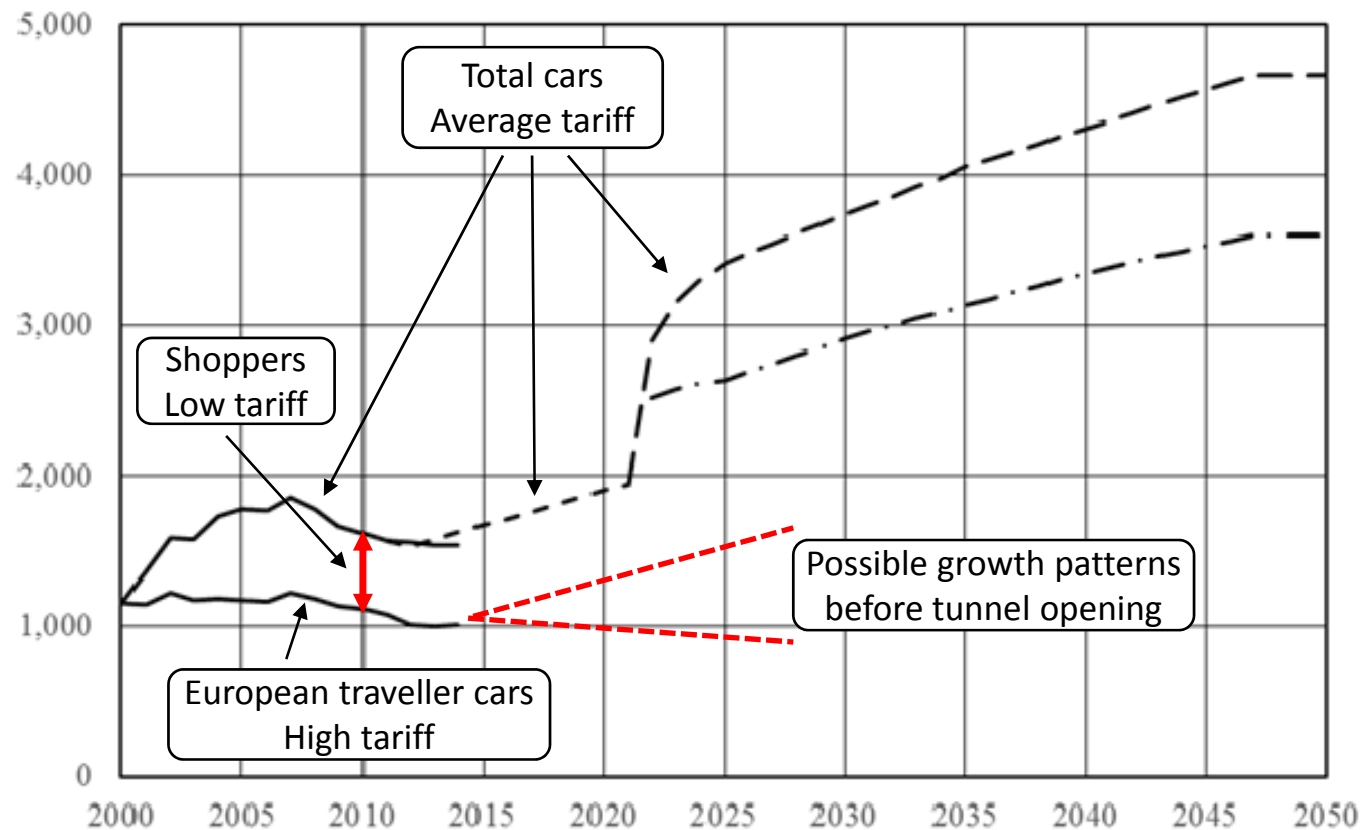


Fig. 1. Fehmarn Belt passenger car traffic (1000 one way cars pr. year).

2000-2014, upper: Realized total cars by ferry (Statistikbanken 2015).

2000-2014, lower: Realized European traveller cars by ferry (Scandlines 2015).

2011-2021: Forecast total cars by ferry (Femern A/S 2014).

2022-2050+, upper: Total cars by tunnel forecasted at average tariff (Femern A/S 2014). Base Case 0, 1' and 1.

2022-2050+, lower: Total cars by tunnel forecasted at average tariff (DIW Econ 2015). Base Case 2.

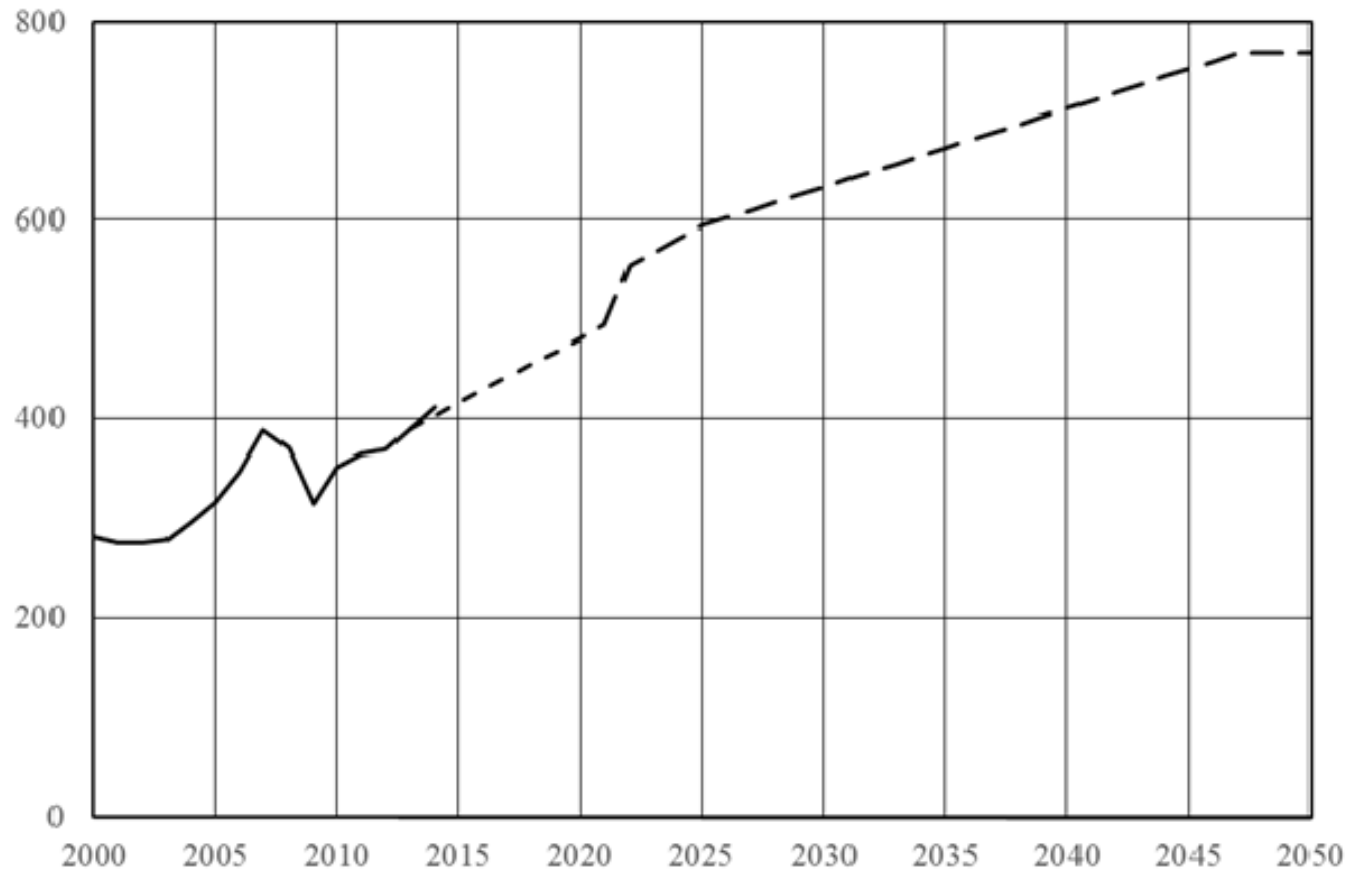


Fig 2. Fehmarn Belt truck traffic (1000 one way trucks pr. year).
 2000-2014: Realized total trucks by ferry (Scandlines 2015).
 2011-2021: Forecast total trucks by ferry (Femern A/S 2014).
 2022-2050+: Forecast total trucks by tunnel, (Femern A/S 2014). Base Case 0, 1, 1' and 2.

Construction costs and reserves (DKK billion, 2014 level)	Nov. 2014 Base Case 0	Nov. 2014 Base Case 1	Feb. 2015 Base Case 1' and 2
Danish landworks			
Construction costs excl. reserves	7.3	7.3	7.3
Correction allowance (10%)	0.7	0.7	0.7
Reserves (20%)	1.5	1.5	1.5
Sum reserves	2.2	2.2	2.2
Sum reserves (%)	30%	30%	30%
Sum construction costs incl. reserves	9.5	9.5	9.5
Coast-to-coast construction			
Construction costs excl. reserves	40.5	40.5	49.4
Reserve for contractor risk	1.8	1.8	1.8
<i>Other reserves:</i>			
Client reserve	3.7	3.7	3.7
Extra reserves (16.4%)		6.7	
<i>Total other reserves</i>	3.7	10.5	3.7
Sum reserves	5.5	12.3	5.5
Sum reserves (%)	14%	30%	11%
Sum construction costs incl. reserves	46.0	52.7	54.9
Total project			
Total construction costs excl. reserves	47.8	47.8	56.7
Total reserves	7.7	14.5	7.7
Total reserves (%)	16%	30%	14%
Total construction costs incl. reserves	55.5	62.2	64.4

Table 1. Project construction costs and reserves.

Base Case 0: Main Scenario (Femern A/S 2014).

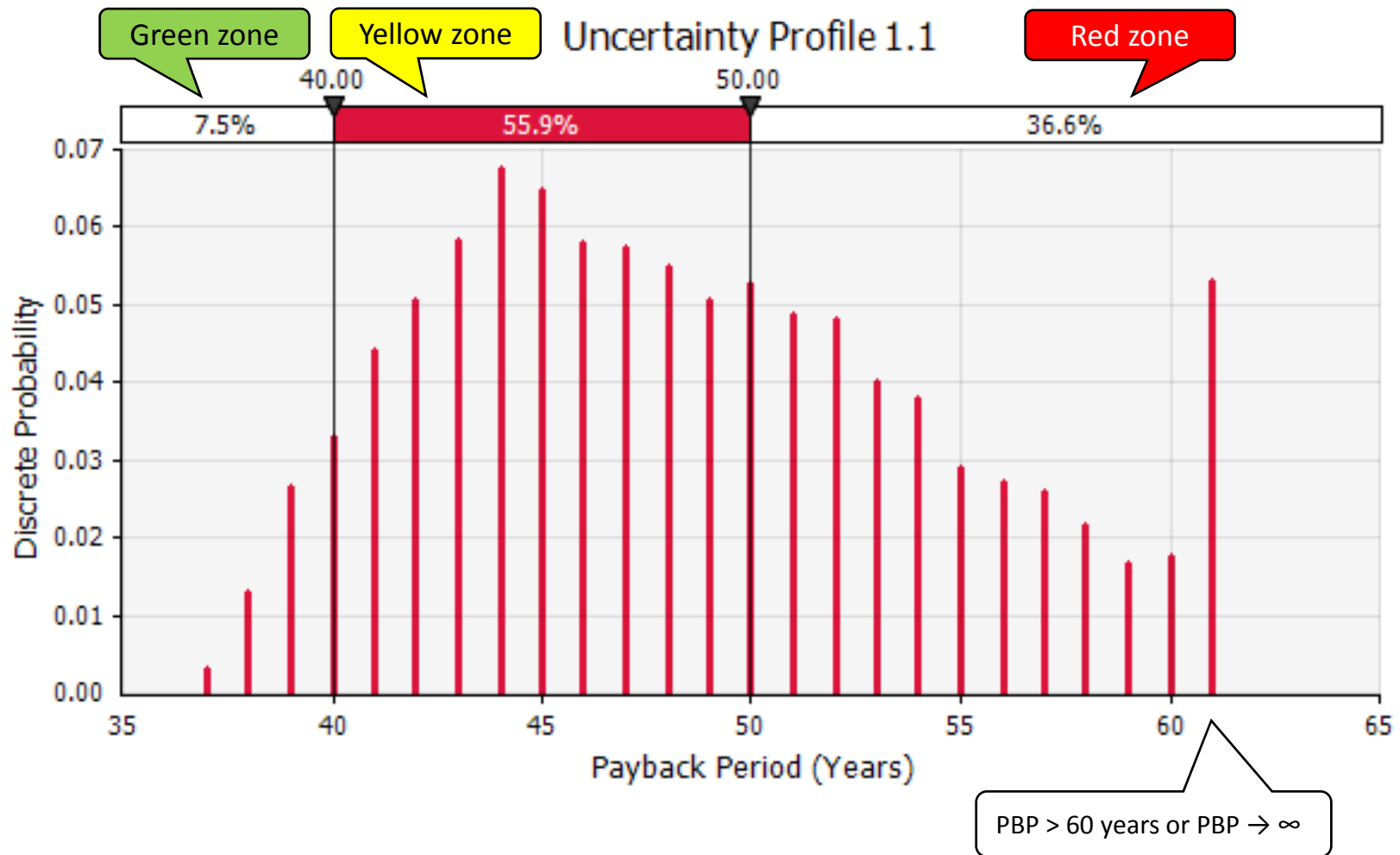
Base Case 1: Total reserves 30% (Femern A/S 2014, Table 20).

Base Case 1' and 2: Coast-to-coast construction costs increased by 22% (Femern A/S 2015).

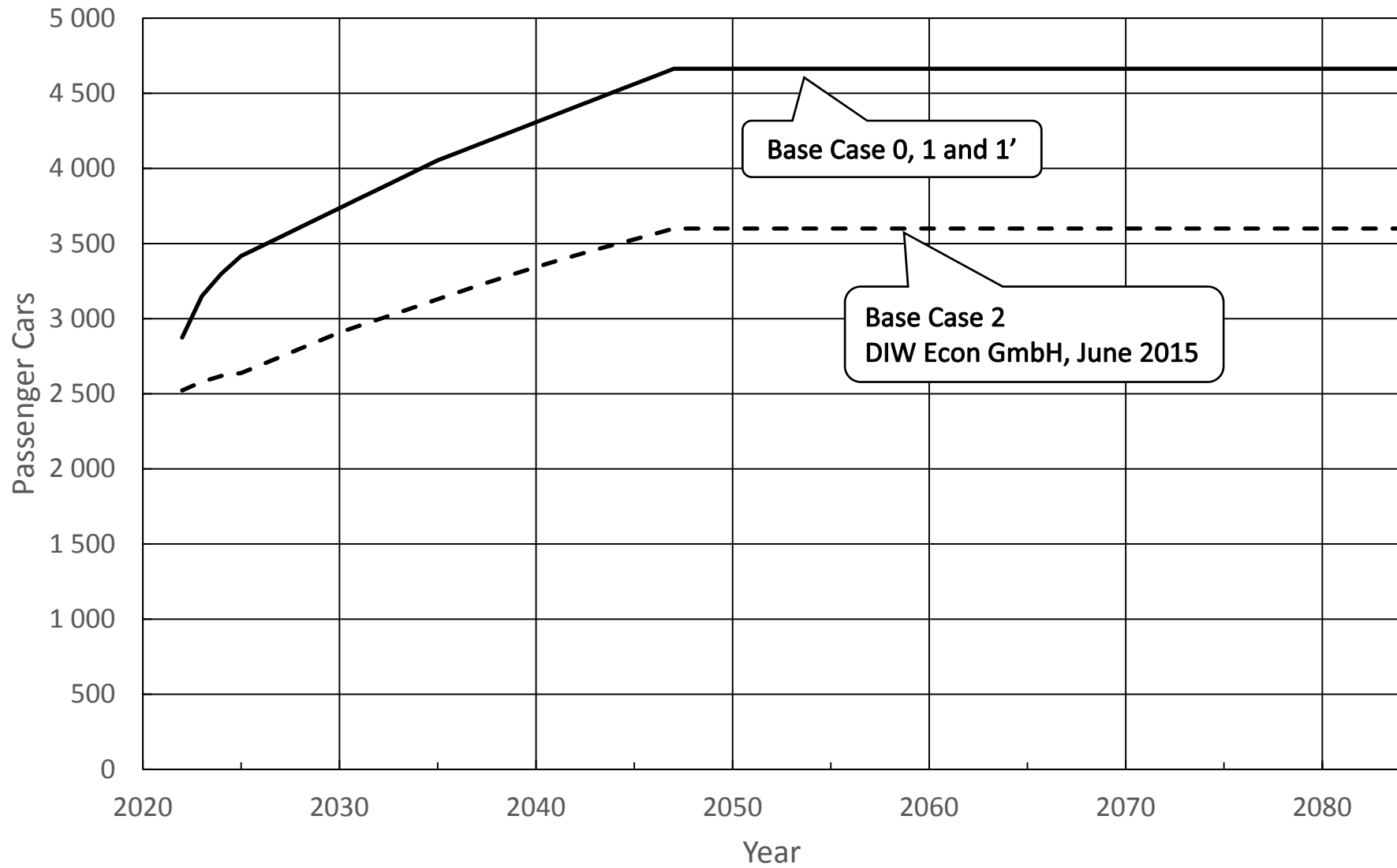
Uncertainty Profile Base Case 1

	Base Case 1	Uncertainty Profile 1.1
Total Traffic Income	[a], Section 5.3	Uniformly distributed factor [0.85; 1.0] 1)
Coast-to-Coast Construction Costs excl. Reserves	DKK 40.5 billion	Uniform distribution DKK [40.5; 49.4] billion
Total Construction Costs incl. Total Reserves	DKK 62.2 billion (Total Reserves 30%)	DKK [62.2; 64.4] billion (Total Reserves [14%; 30%])
EU Subsidies	DKK 10.3 billion	Uniform distribution DKK [4.4; 10.3] billion
Payback Period by Monte Carlo simulation (years)	37 years	50 < PBP: 36.6%
		40 < PBP ≤ 50: 55.9%
		PBP ≤ 40: 7.5%
Payback Period by Interval Analysis (years)		[37; >60]
Notes	Extra coast-to-coast reserves of DKK 7.4 billion (16.4%)	Uncertain road traffic income, coast-to-coast construction costs, and EU subsidies

[a] Femern A/S, "Financial analysis of the Fehmarnbelt Fixed Link including Danish landworks, November 2014.
1) Uncertainty factor on road traffic income.



Fehmarn Belt Passenger Car Traffic Forecasts



Base Case 2 with uncertainty profile

	Base Case 2	Uncertainty Profile 2.1
Total Traffic Income	Passenger car traffic volume as estimated in [a], Table 11	Triangularly distributed factor [0.9; 1.0; 1.3] 1)
Coast-to-Coast Construction Costs excl. Reserves	DKK 49.4 billion	Uniform distribution DKK [40.5; 49.4] billion
Total Construction Costs incl. Total Reserves	DKK 64.4 billion (Total Reserves 14%)	DKK [62.2; 64.4] billion ([14%; 30%])
EU Subsidies	DKK 4.4 billion	Uniform distribution DKK [4.4; 10.3] billion
Payback Period by Monte Carlo simulation (years)	This model: >60 years	50 < PBP: 87.7%
		40 < PBP ≤ 50: 12.3%
		PBP ≤ 40: 0.0%
Payback Period by Interval Analysis (years)		[48; >60]
Notes	Passenger car volume reduced due to changed route preferences	Uncertain passenger car volume, coast-to-coast construction costs, and EU subsidies

[a] R. Aigner, F. Pavel, K. Weber, "How robust are the economic analyses of the fixed Fehmarn Belt link?", DIW-Econ, Berlin, June 2015. (Commissioned by Scandlines, in German).

1) Uncertainty factor on passenger car volume.

4. Recent financial analysis of February 2016

Base Case construction costs (DKK billion)	Nov. 2014 Base Case 0	Nov. 2014 Base Case 1	Feb. 2015 Base Case 1'	Apr. 2015 L141	Feb. 2016
Price level	2014	2014	2014	2015	2015
Danish landworks					
Construction costs excl. reserves	7.3	7.3	7.3	7.3	7.3
Correction allowance (10%)	0.7	0.7	0.7	0.7	0.7
Reserves (20%)	1.5	1.5	1.5	1.5	1.5
Sum reserves	2.2	2.2	2.2	2.2	2.2
Sum reserves (%)	30%	30%	30%	30%	30%
Sum construction costs incl. reserves	9.5	9.5	9.5	9.5	9.5
Coast-to-coast construction					
Construction costs excl. reserves	40.5	40.5	49.4	45.8	38.9
Reserve for contractor risk	1.8	1.8	1.8		
<i>Other reserves:</i>					
Client reserve	3.7	3.7	3.7		
Extra reserves (16.4%)		6.7			
<i>Total other reserves</i>	3.7	10.5	3.7		
Sum reserves	5.5	12.3	5.5	3.7	7.3
Sum reserves (%)	14%	30%	11%	8%	19%
Project preparation, organisation etc.				5.6	6.4
Sum construction costs incl. reserves	46.0	52.7	54.9	55.1	52.6
Total project					
Total construction costs excl. reserves	47.8	47.8	56.7	53.1	52.6
Total reserves	7.7	14.5	7.7	5.9	9.5
Total reserves (%)	16%	30%	14%	11%	18%
Total construction costs incl. reserves	55.5	62.2	64.4	64.6	62.1
Payback Period	32 years	37 years	39 years	39 years	36 years

Table 13. Update from February 2015 to February 2016

	Basis in the Construction Act, February 2015	39 years
A	Updated traffic forecasts and actual interest conditions on Øresund and the Great Belt	-1 year
B	Reduction of railway funding for Øresund and Storebælt and commuter discount on the Great Belt	+1 year
C	Bringing forward taxation of EU funding to the time of disbursement	+½ year
D	Deduction for construction loan interest in Germany	-½ year
E	Adjustment of the traffic forecast to technically assumed opening in mid-2026	-1 year
F	Adjustment of construction sum for lower historical inflation	-1 year
G	Efficiency improvement of operation, maintenance and reinvestment, coast-to-coast section	-2 years
H	Reduction of assumptions of EU funding in the construction phase from 18 per cent to 10 per cent	+4 years
I	Reduced construction sum as a result of new bids as of 15 September 2015	-3 years
	Repayment time on commencement of construction at the beginning of 2018 and opening in mid-2026. Reserve fully used	36 years
	Repayment time on commencement of construction at the beginning of 2020 and opening in mid-2028. Reserve fully used	36 years

Table 14: Overview of partial sensitivity calculations			Table 14.1 – 14.14
No.	Parameter	Change	Change PBP
1	Construction costs, coast-to-coast section	<p>Full drawdown on the overall budget of the Construction Act: DKK 55.1 billion (+DKK 2.5 billion)</p> <p>Baseline: DKK 52.6 billion</p> <p>Lower drawdown on reserves: DKK 50.6 billion (-DKK 2 billion)</p>	<p>+ 2 years</p> <p>- 2 years</p>
2	Construction costs, Danish landworks	<p>Baseline: DKK 9.5 billion</p> <p>Lower drawdown on reserves: DKK 0.7 billion (- DKK 1.5 billion)</p>	- 1 year
3	Operation, maintenance and reinvestment, coast-to-coast section	<p>+DKK 50 million per year</p> <p>Baseline: DKK 468 million per year</p> <p>-DKK 50 million per year</p>	<p>+ 1 year</p> <p>-1 year</p>
4	Operation, maintenance and reinvestment, Danish landworks	<p>+DKK 25 million per year</p> <p>Baseline: DKK 239 million per year</p> <p>-DKK 25 million per year</p>	<p>+ less than 1 year</p> <p>- less than 1 year</p>
5	EU funding	<p>No further funding in addition to the already allocated framework of DKK 4.4 billion (-DKK 1,4 billion)</p> <p>Baseline: DKK 5.8 billion</p> <p>+DKK 1 billion</p> <p>+DKK 2 billion</p>	<p>+ 1 year</p> <p>-1 year</p> <p>- 2 years</p>

6	Real interest rate	3.5 per cent Baseline: 3.0 per cent 2.5 per cent	+ 7 years - 5 years
7	Redistribution of passenger car traffic from the Great Belt	-500 cars per day Baseline: 1,967 cars per day +500 cars per day	+ 2 years - 2 years
8	New traffic and dynamic effects	Baseline: No dynamic effects Impact of dynamic effects: 20% new traffic	- 5 years
9	Jump in traffic	25 per cent 40 per cent Baseline: 54 per cent	+ 10 years + 3 years
10	Average annual traffic growth during the first 25 years of operation	-10 per cent traffic growth Baseline: 1.4 per cent traffic growth per year +10 per cent traffic growth	+ 3 years - 3 years


11	Continued ferry service	<p>1-hourly service, temporary 2-hourly service, temporary 1-hourly service, permanent 2-hourly service, permanent -25 per cent ferry fare</p> <p>Baseline: No ferry service</p>	 <p>+ 12 years + 8 years + 1 year + 1 year</p>
12	Differentiated fares on the fixed link	<p>Baseline: Flat price structure Differentiated price structure</p>	- 1 year
13	Continued ferry service with shopping discount on both ferry and tunnel	<p>Half-hourly ferry service with -25 per cent shopping ticket price and -25 per cent shopping ticket price in the tunnel</p> <p>Baseline: No ferry service and a flat fare structure</p>	+ 3 years
14	Delay of the German plan approval	<p>Commencement of construction at the beginning of 2022, opening of the fixed link in mid-2030</p>	+ less than 1 year

Table 16: Stress test relative to an assumed maximum repayment time of 50 years		
No.	Parameter	Maximum change
1	Construction costs for the overall Fehmarnbelt project, including the Danish landworks	+DKK 11.7 billion or +19 per cent, equivalent to total costs of DKK 73.7 billion
2	EU funding during the construction phase	Lapse of EU funding in the construction phase: Repayment time of 42 years, i.e. less than 50 years
3	Traffic revenue from the road section of the link	-16 per cent per year equivalent to approx. DKK 500 million less in 2031 and approx. DKK 630 million less by 2053 onwards
4	Average real interest rate on the project's interest-bearing debt	3.8 per cent p.a., equivalent to a nominal interest rate of 5.9 per cent p.a.

Quality Assurance Issue: Passenger car transfer from the Great Belt to the Fehmarn Belt fixed link

- Official forecast: 40% of 66% traffic jump is transferred from Great Belt
- COWI, 10 Nov. 2015: "Especially the expected transfer of passenger car traffic from the Great Belt is difficult to document due to lack of data of the present traffic pattern crossing the Great Belt"
- Minister of Transportation in press release, 12 Nov. 2015: "COWI has found that the traffic forecast is thorough and gives a realistic estimate of the traffic volume in the tunnel"
- Presenter in *Børsen*, 26 Nov. 2015: "Minister neglects serious criticism of Fehmarn"
- Ministry of Transport (quoted from *Ingeniøren*, 31 Mar. 2016): "By the way, Sund & Bælt has been commissioned to analyze the international traffic crossing the Great Belt fixed link in order to establish further documentation of the potential volume of transfer of passenger car traffic from the Great belt to the Fehmarn Belt"
- Sund & Bælt, 9 Aug. 2016: Result of above analysis is available to the Ministry of Transport by January 2017

5. Lessons to be learned

- Many Base Case input variables are not central estimates but rather one-sided optimistic estimates
- No risk profiles presented - partial sensitivity analyses underestimate total uncertainty
- *Post-decision* external quality assurance (non-conformity with *New Budgetting*)
- External quality assurance reports leave a lot of unanswered questions
- No external quality assurance of consolidated financial analyses incl. uncertainty
- The Fehmarn Belt immersed tunnel is still a high risk business case