High-Speed Railway Lines in Norway

Concept Evaluation, Cost Estimate and Uncertainty Analysis

Report 2: Quantitative results for all corridors

Report to Jernbaneverket

Classification: None

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Date: October 31th, 2007

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CONSULTING

Executive Summary

Commission

Jernbaneverket has commenced an initiative, comprising three phases, to evaluate the strategy for high-speed railway lines in Norway. Metier AS has been asked to facilitate concept evaluations and the establishment of investment cost estimates including uncertainty analysis of the planned new corridors in Norway.

The analysis is based on information that was gathered, assessed and scrutinized in multidisciplinary workshops to obtain the most unbiased and complete picture of the project.

Operational and Technical Concept - Planning reference

The superior operational concepts – as a planning reference - are defined based on the objective of "ousting air traffic on the distance at lowest cost". Key parameters and assumptions are given in section 1.5. The key-assumptions are:

1. Design speed 250 kph, exceptions on particular difficult parts
2. Train service: Hourly service in peak time for all corridors
3. Freight traffic: No daytime freight traffic on any of the corridors, except the corridor Oslo – Gøteborg that can be combined with freight traffic.
4. Technology: Based on today's technology, except for some special tunnels and special constructions for fjord-crossings.
5. Single-track lines on all corridors, except for the corridors Oslo to Bergen and Stavanger via Haukeli which are double-track lines.

Investment Costs

The present investment cost estimates include necessary infrastructure and trains. Unit prices are based on prices from recently finished and ongoing comparable railway projects in Norway and Sweden. Future price escalation is not included in the present analysis according to ordinary planning guidelines for large public projects in Norway. The below diagram illustrates, for each corridor, the expected cost per length of new track in addition to share of bridges, tunnels and open line.

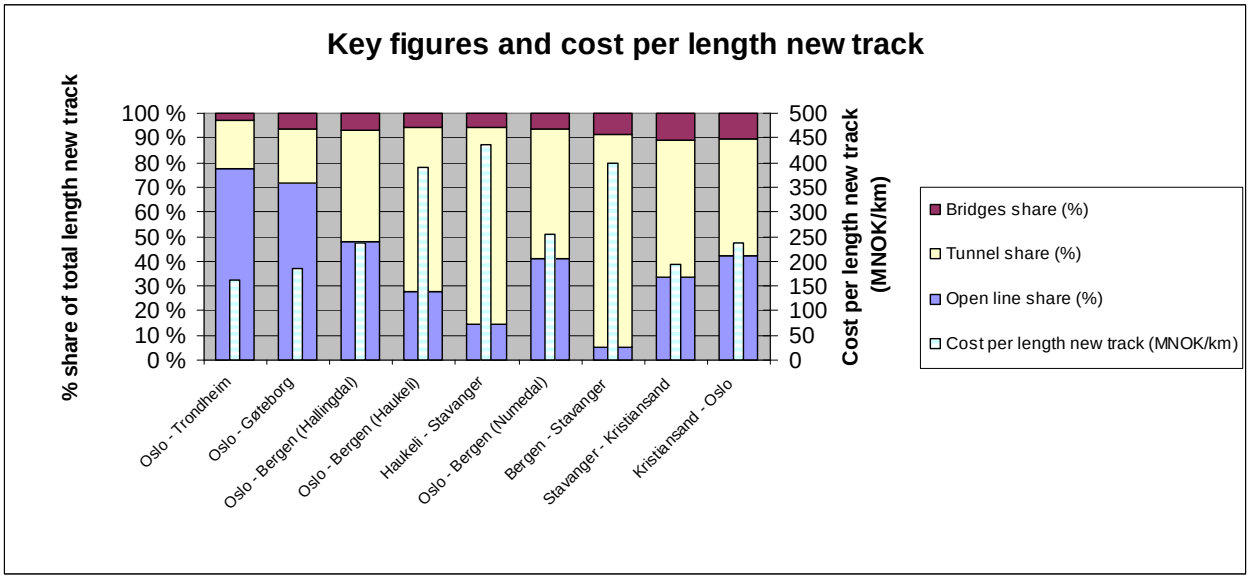

Figure 1 Key figures and cost per length new track

The three major uncertainties are:

- Level of planning: The project foundation is at prefeasibility level and is thus bond with high uncertainty in general.
- Contractors and materials market: This is mainly due to the risk of major shortages in contractor capacity. A heated world market in materials may amplify this effect.
- Project ownership: This is mainly due to the risk of a non-optimal funding program, program deviations and owners indecisiveness.

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1 Introduction

1.1 Commission

Jernbaneverket has commenced an initiative, comprising three phases, to evaluate the strategy for high-speed railway lines in Norway. Metier AS has been asked to facilitate concept evaluations and the establishment of investment cost estimates including uncertainty analysis of the planned new corridors in Norway.

The present report comprises the following corridors and new tracks:

- Corridor Oslo – Trondheim: New track Sørli - Heimdal
- Corridor Oslo – Gøteborg: New track Råde – Swedish border
- Corridor Oslo – Bergen via Hallingdalen: New track Hønefoss - Bergen
- Corridor Oslo – Bergen via Haukeli: New track Drammen - Bergen
- Corridor Haukeli – Stavanger: All new track
- Corridor Oslo – Bergen via Numedalen: New track Drammen - Bergen
- Corridor Bergen – Stavanger: All new track
- Corridor Stavanger – Kristiansand: All new track
- Corridor Oslo – Kristiansand: New track Porsgrunn - Kristiansand

1.2 Disposition

The present report should be considered as an amendment and only be considered in conjunction with the report: “High-Speed Railway Lines in Norway – Concept evaluation, Cost Estimate and Uncertainty Analysis - Report 1: Basic assumptions and methodology, and calculations for the corridor Trondheim – Oslo, Rev. 2.2, dated September 11th, 2007”.

Appendix 1 gives a brief summary of the participant of the study and the approach and methodology used.

Detailed analysis input data is presented in the following appendices:

- Appendix 2 Generic estimate structure
- Appendix 3 Input: Deterministic Estimate - Quantities
- Appendix 4 Input: Deterministic Estimate - Unit Prices
- Appendix 5 Input: Uncertainty Analysis – Cost Elements
- Appendix 6 Input: Uncertainty Analysis – Uncertainty Drivers
- Appendix 7 Input: Uncertainty Analysis – Correlations

Note! There might be minor result deviations between and within the reports due to different simulation runnings.

1.3 Document Basis

[1] Feasibility Study Concerning high-speed railway lines in Norway, Report Phase 1, 2006-12-15

[2] Feasibility Study Concerning High-Speed Railway Lines in Norway, WP 300: High-Speed-Railway-Specific Conditions, 2006-12-19

[3] Map, scale 1:250.000

[4] High-Speed Railway Lines in Norway – Concept evaluation, Cost Estimate and Uncertainty Analysis - Report 1: Basic assumptions and methodology, and calculations for the corridor Trondheim – Oslo, Rev. 2.03, dated October 30th, 2007

[5] High Speed Railway Lines in Norway – Power Supply Converter Stations including High Voltage Supply - Input to Cost Estimate, Rev.000, dated august 21st, 2007

[6] Kvalitetssikring grunnerverv, memo, august 29th, 2007

[7] Hengebru som jernbanebru, memo from Aas Jacobsen, september 4th, 2007

1.4 General Analysis Assumptions

The analysis is based on the following general assumptions:

Cost Basis:	2007 Norwegian kroner
Future Price Escalation (inflation):	Not included in the present analysis according to ordinary planning guidelines for large public projects in Norway. Metier's comment: Price escalation for construction projects has in recent years been larger than the regular inflation. This is basically due to material price and salary escalations.
Finances:	Government allowances with project optimized funding and professional ownership. Finance costs (e.g. interest on building loans is not included).
Government Dues:	All numbers are exclusive of VAT according to prevailing regulations for railway in Norway.
Planned Schedule for the investments:	Not detailed out on this planning level.
Removal of old lines:	Removal of old line is not included in the cost estimate. Use of existing lines is not decided at this planning level.
Market and contracts:	Balanced market (Europe) through long term market development strategies. Unit price contracts. The implementation of such a project could overheat the construction market and jeopardise normal price relations for the whole business line. It may be argued, however, that given predictable financing conditions and large, long horizon contracts, this kind of large project will create its own market much like the situation has been for the oil & gas and hydropower industries

1.5 Project/corridor descriptions

Lengths of corridors (km)	Oslo - Trondheim	Oslo - Gøteborg	Oslo - Bergen (Hallingdal)	Oslo - Bergen (Haukeli)	Haukeli - Stavanger	Oslo - Bergen (Numedal)	Bergen - Stavanger	Stavanger - Kristiansand	Kristiansand - Oslo
Length of existing high speed railway track	108	52	0	41	0	41	0	0	0
Length of planned high speed railway track	12	23	57	0	0	0	0	15	171
Length of new track (km) Topic of this report	**366**	**70**	**338**	**370**	**150**	**364**	**221**	**194**	**162**
Assumed length of track in Sweden		205							
Sum Total length of corridors	486	350	395	411	150	405	221	209	333

Table 1 Lengths of corridors in km. Note! It is only the previous unplanned new track that is assessed in the report.

Note that the corridors listed below noted “Existing and planned high speed railway” only comprises parts applicable to high speed standards. Despite their restrictions with respect to speed, they will be used by the high speed railway.

Detailed assumptions:

Oslo – Trondheim

Existing and planned high speed railway: Trondheim – Heimdal (12 km), Sørli – Eidsvoll (ca. 42 km) and Eidsvoll – Oslo (ca 66 km)

New track: Heimdal – Sørli (366 km): Topic of the report *Concept evaluation, Cost estimate and Uncertainty Analysis*, doc.no 1 dated May 29th 2007.

Oslo – Gøteborg

Existing and planned high speed railway: Oslo – Ski (already planned, 23 km), Ski – Moss (already built, 35 km), Moss – Råde (partly built, 17 km) and Swedish border – Gøteborg (205 km)

Existing lines not anticipated for high speed concept (160 to 200 kph)

New track: Råde – Swedish border (70 km)

Oslo – Bergen via Hallingdalen

Existing and planned high speed railway: Oslo – Sandvika (14 km) and Sandvika – Hønefoss (43 km)

New track: Hønefoss – Bergen (338 km)

Oslo – Bergen via Haukeli

Existing and planned high speed track: Oslo – Drammen (41 km)

New track: Drammen – Bergen (370 km)

Haukeli – Stavanger

New track: Haukeli – Stavanger (150 km)

Oslo – Bergen via Numedalen	Existing and planned high speed railway: Oslo - Drammen (41 km) New track: Drammen – Bergen (364 km)
Bergen – Stavanger	New track: Bergen – Stavanger (221 km)
Stavanger – Kristiansand	Existing and planned high speed railway: Stavanger - Sandnes (max speed 95 kph, 15 km) New track: Sandnes – Kristiansand (194 km)
Oslo – Kristiansand	Existing and planned high speed railway: Oslo – Porsgrunn (171 km, planned Oslo – Porsgrunn, 160 to 200 kph with some exceptions) New track: Porsgrunn – Kristiansand (162 km)

2 Operational and Technical Concept - Planning reference

The following superior technical concept was defined based on the objective of "ousting air traffic on the distance at lowest cost".

Technical concept	Oslo - Trondheim	Oslo - Gøteborg	Oslo - Bergen (Hallingdal)	Oslo - Bergen (Haukeli)	Haukeli - Stavanger	Oslo - Bergen (Numedal)	Bergen - Stavanger	Stavanger - Kristiansand	Kristiansand - Oslo
Technical concept	Single-track	Single-track	Single track	Double-track	Double-track	Single track	Single track	Single-track	Single-track
No. of. crossing sections (type rhomboid 12 km)	3	1	2	0	0	2	1	1	2
Maximum track gradient (‰)	25	12.5	30	12.5	20	30	20	12.5	16
Special tunnel aspects	None	None	None	None	One subsea-tunnel (Boknafjorden, 55 km)	None	Two subsea-tunnels (Boknafjorden, 55 km and Stord-Sveio 43 km)	None	None
Special constructions	None	None	None	Crossing of Hardangerfjord	None	None	Crossing of Samnangerfjord and Tyssnes-Stord	None	Crossing of Porsgrunns-elven and Topdalsfjord

Table 1 Technical parameters and assumptions

General operational and technical assumptions:

1. Design speed 250 kph, except on particular difficult parts
2. Train service: Hourly service in peak time for all corridors
3. Technology: Based on today's technology, except for the special tunnels and special constructions mentioned above.
4. Tracks: Traditional ballast tracks on open line and slabtrack in long tunnels
5. Signalling system: ERTMS-2 and use of GSMR and GPRS
6. Tunnels:
   - Size: 75 m^2
   - Tunnel rescue according to EU requirements. Double-track: Connections every 500 m. Single track: Exits every 1000 m.
   - Single track concept: Single track as much as possible. For tunnels longer than 10 km: Twin tunnels, one for rescue (same size). For shorter tunnels rescue-tunnels have size: 35 m^2. Using existing tunnels as rescue-tunnels at Finse and Voss – Bergen.
7. Freight traffic: No daytime freight traffic on any of the corridors, except the corridor Oslo – Gøteborg that can be combined with freight traffic.

3 Results

The table below presents a summary of the results derived from the analysis.

Results	Oslo - Trondheim	Oslo - Gøteborg	Oslo - Bergen (Hallingdal)	Oslo - Bergen (Haukeli)	Haukeli - Stavanger	Oslo - Bergen (Numedal)	Bergen - Stavanger	Stavanger - Kristiansand	Kristiansand - Oslo
Expected investment cost of project (MRDK)	59	13	80	144	66	92	89	38	38
Standard deviation (MRDK)	16	4	24	45	19	28	26	11	11
Standard deviation (% of expected cost)	27 %	27 %	30 %	31 %	29 %	31 %	30 %	29 %	29 %
Expected cost (MNOK) per lenght of new track (km)	162	186	237	389	441	253	403	194	235

Table 2 Summary results (MRDK)[1]

[1] Note! There might be minor result deviations between and within the reports due to different simulation runnings.

The results are presented in the below figure, illustrating the expected investment cost for the corridors and the expected cost per length of new track.

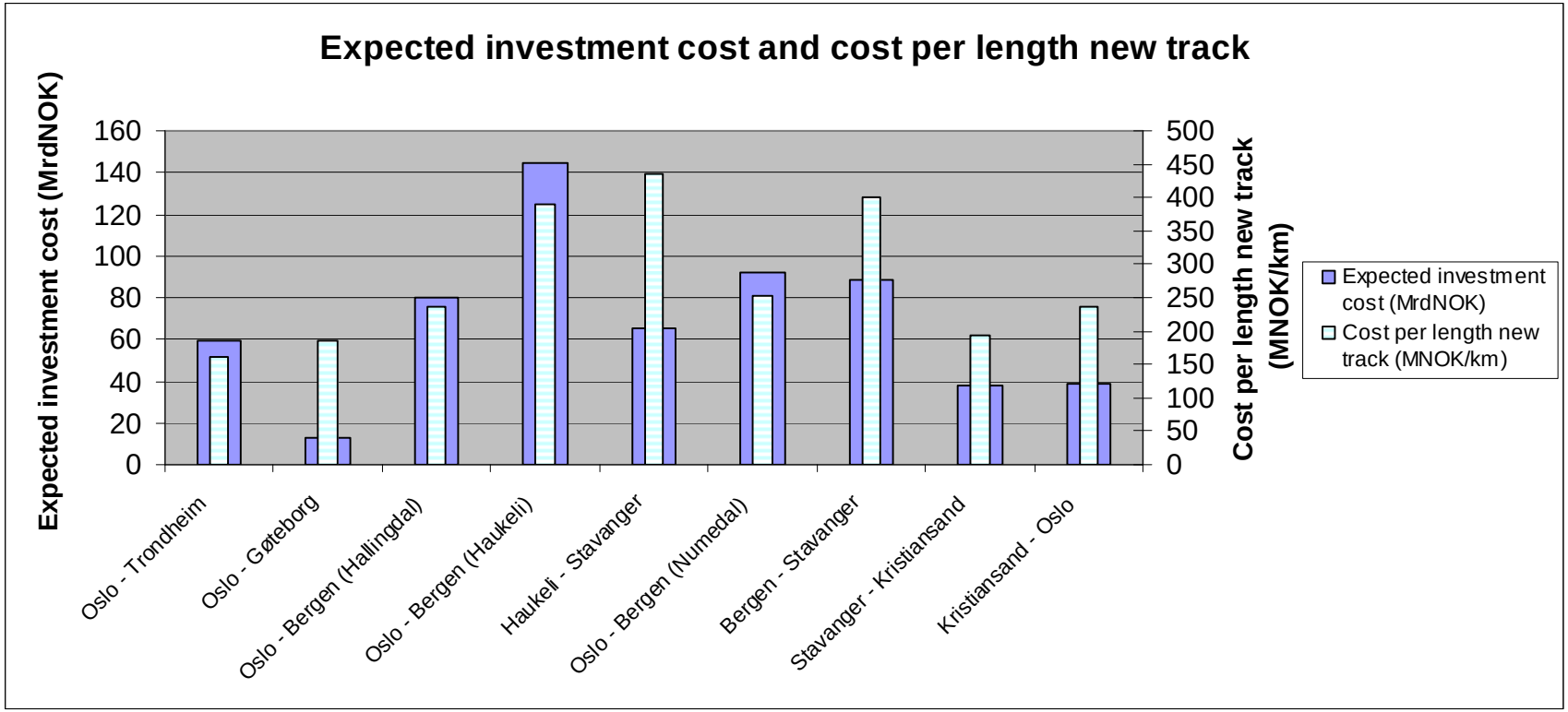

Figure 2 Expected investment cost and cost per length new track for all corridors.

The table below presents detailed results in terms of main cost elements for the corridors.

Main Cost Elements	Details	Oslo - Trondheim	Oslo - Gøteborg	Oslo - Bergen (Hallingdal)	Oslo - Bergen (Haukeli)	Haukeli - Stavanger	Oslo - Bergen (Numedal)	Bergen - Stavanger	Stavanger - Kristiansand	Kristiansand - Oslo
Tunnel (without superstructure)	Tunnel lenght and fixed sites. Additions for service tunnel, crossing sections in tunnels, soil tunnels and longer portals.	8,5	1,8	26,0	39,9	27,0	34,3	31,9	12,7	9,3
Open line	New open line sections. Additions for silt/soft soil and high/low cuts and fills.	14,4	2,7	9,0	10,1	1,6	7,1	0,5	2,0	4,0
Constructions	Wildlife crossings, road crossings including connections, reconstruction of local infrastructure and railway bridges.	2,3	0,8	4,2	19,0	2,5	4,2	12,4	2,7	3,3
Superstructure	Regular line. Additions for crossings and slabtrack.	9,3	1,8	9,0	19,7	8,3	9,8	9,3	5,3	4,5
Stations	Large and small stations.	0,1	0,1	0,3	0,4	1,2	0,6	1,2	0,0	1,6
Power supply	Power supply substations.	0,4	0,0	0,3	0,4	0,1	0,3	0,2	0,2	0,2
Special infrastructure	Special support constructions.	0,3	0,0	0,1	0,3	0,0	0,3	0,0	0,0	0,0
Facilities	Service and maintenance facilities.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Contractor Costs		**35,4**	**7,3**	**48,9**	**89,7**	**40,6**	**56,6**	**55,5**	**23,0**	**22,9**
Management and Engineering	Contractor/client management and engineering.	10,6	2,2	14,7	26,9	12,2	17,0	16,6	6,9	6,9
Land acquisitions	Land acquisitions	0,5	0,3	0,6	0,3	0,1	0,5	0,0	0,1	0,2
Project Cost		**46,4**	**9,8**	**64,3**	**116,9**	**52,8**	**74,2**	**72,2**	**30,0**	**30,1**
Trains and facilities	Trains and maintenance facilities	3,1	1,1	1,4	1,4	1,4	1,4	0,8	0,8	1,4
Total Investments		**49,5**	**10,9**	**65,7**	**118,4**	**54,2**	**75,6**	**73,0**	**30,8**	**31,5**
Uncertainty Drivers		9,7	2,1	14,3	25,4	11,9	16,6	16,0	6,7	7,0
Total Estimate		**59,2**	**13,0**	**80,0**	**143,8**	**66,1**	**92,2**	**89,0**	**37,6**	**38,5**

Table 3 Summary results (MrdNOK) [2]

[2] Note! There might be minor result deviations between and within the reports due to different simulation runnings.

4 Conclusion

The analysis is based on information that was gathered, assessed and scrutinized in multidisciplinary workshops to obtain the most unbiased and complete picture of the project.

Operational and Technical Concept - Planning reference

The superior operational concepts – as a planning reference - are defined based on the objective of "ousting air traffic on the distance at lowest cost". Key parameters and assumptions are given in section 1.5. The key-assumptions are:

1. Design speed 250 kph, exceptions on particular difficult parts
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5. Single-track lines on all corridors, except for the corridors Oslo to Bergen and Stavanger via Haukeli which are double-track lines.

Investment Costs

The present investment cost estimates include necessary infrastructure and trains. Cost basis is 2007 Norwegian kroner. Unit prices are based on prices from recently finished and ongoing comparable railway projects in Norway and Sweden. Future price escalation is not included in the present analysis according to ordinary planning guidelines for large public projects in Norway. Other general assumptions are documented in chapter 2 "Operational and Technical Concept - Planning reference".

The below diagram illustrates, for each corridor, the expected cost per length of new track in addition to share of bridges, tunnels and open line.

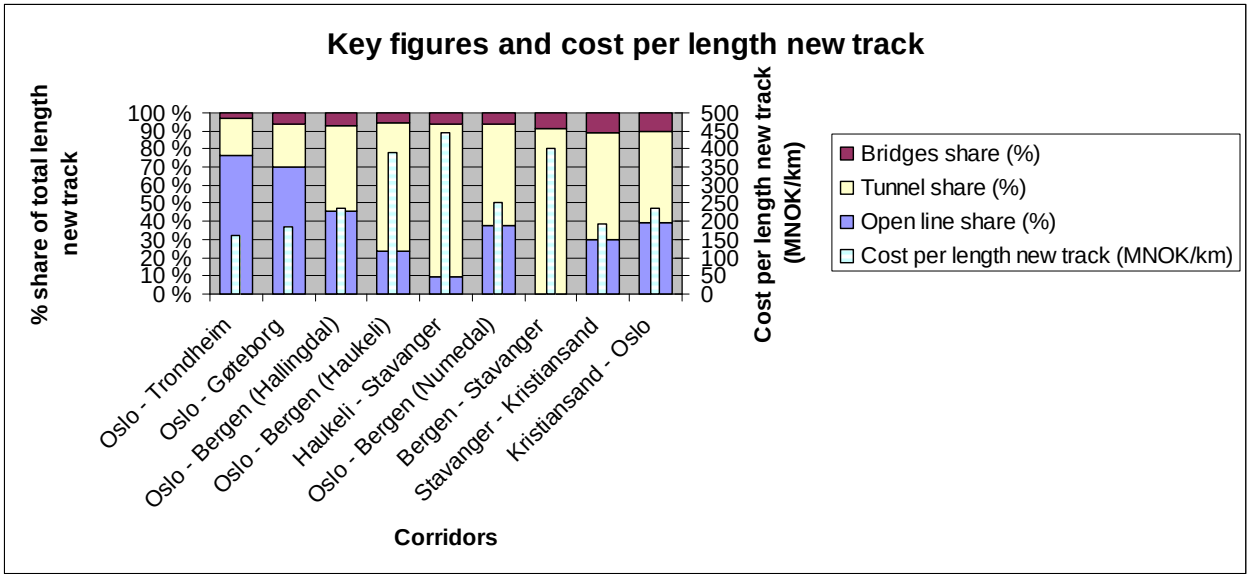

Figure 3 Key figures and cost per length new track

The three major uncertainties are:

- Level of planning: The project foundation is at prefeasibility level and is thus bond with high uncertainty in general.
- Contractors and materials market: This is mainly due to the risk of major shortages in contractor capacity. A heated world market in materials may amplify this effect.
- Project ownership: This is mainly due to the risk of a non-optimal funding program, program deviations and owners indecisiveness.

Appendix 1 Study approach – Details

Main approach and group meetings

The analysis is based on information that was gathered, assessed and scrutinized in multidisciplinary workshops to obtain the most unbiased and complete picture of the project. The team included people from the German group of VWI with partners, Jernbaneverket, Sintef, NGI, Direktoratet for Naturforvaltning, Asplan Viak and Metier. Metier facilitated the workshops.

The input to the concept evaluation and uncertainty analysis has been gathered in workshops with different experts. The most important workshops for the corridor Oslo – Trondheim have been:

- February 27-28.: Concept evaluation, estimation of quantities and uncertainty analysis
- March 2.: Need Energy-supply/consumption
- March 23.: Commissioning of uncertainty analysis

- The most important workshops for the other corridors have been:
- June 19-20.: Concept evaluation, estimation of quantities and uncertaint analysis
- August 14-15.: Concept evaluation, estimation of quantities and uncertaint analysis

The following table presents the group-sessions participants.

Name	Role in study/Competance	Company	Workshops							
			27.2	28.2	2.3	23.3	19.6	20.6	14.8	15.8
Peter Sautter	Alignment, costs	IGV	X	X	X	X	X	X	X	X
Jochen Rowas	Alignment, costs	LFS	X	X	X					
Finn Holom	Railway alignment	JBVU		X						
Christian Knittler	High speed expert	JBV	X	X			X		X	X
Per Herman Sørlie	Railway alignment	JBVU	X	X		X	X		X	X
Runar Gravdal	Costs	JBVU	X	X		X	X		X	X
Frode Johnsen	Energy-supply/consumption	JBV			X			X		
Roger Olsson	Geology	NGI	X	X		X	X		X	X
Anders Beitnes	Tunnel	SINTEF	X	X		X	X		X	X
Terje Eidsmoen	Railway	JBV	X	X			X			
Halstein Gåsemyr	Wheel/track	JBV	X	X			X			
Erik Stabell	Environmental impacts	Direktoratet for naturforvalting	X	X			X			

Name	Role in study/Competance	Company	Workshops							
			27.2	28.2	2.3	23.3	19.6	20.6	14.8	15.8
Randi Birgitte Svånå	Projectleader Jernbaneverket	Asplan Viak	X	X		X	X		X	X
Paul Torgersen	Facilitator	Metier	X	X	X	X	X	X	X	X
Jan Erik Eldor	Facilitator	Metier	X	X	X	X	X	X	X	X

Table 2 Contributors to the analysis (participation on workshops)

Method for concept evaluation and establishment of deterministic cost estimate

The Concept Evaluation and establishment of the deterministic estimate consisted of the following activities:

1. Establishment of a most likely operational concept based on the input from the Feasibility Study from the VWI with partners.
2. Establishment of key parameters and assumptions.
3. Establishment of investment cost estimate structure on pre-feasibility level including descriptions and delimitations of cost-elements.
4. Evaluation and re-estimation of quantities.
5. Estimation of unit prices based on relevant reference-projects.

Method for the Uncertainty Analysis

The Uncertainty analysis has been performed according to Metier's standard methodology for uncertainty analysis The Complete Risk Manager, using the software tools Risk View and Crystal Ball.

The quantitative analysis is based on a 10/90 model, meaning that the extremities in the triple estimates are quoted as the 10 %-percentile for the minimum value and the 90 %-percentile for the maximum value. All parameters are assumed triangular distributed. The mean value, standard deviation and sensitivities are found by Monte Carlo simulation.

The following main activities were performed:

1. Project characteristics and situation map. The situation map is a graphical representation of the group's understanding of the project with respect to specific parameters.
2. Identification of uncertainties facing the concepts.
3. Grouping uncertainties into uncertainty drivers in addition to scenario descriptions of the uncertainty drivers into a planning reference, a best-case scenario and a worst-case scenario.
4. Quantitative cost analysis, comprising distribution curves and uncertainty profiles, including standard deviation and specific percentiles.
5. Action/activities prioritization and conclusions.
6. Deterministic estimate - Quantities

Appendix 2 Generic estimate structure

The table below present the generic estimate structure – example corridor Trondheim – Oslo.

Cost estimate (deterministic/most likely)

Cost elements			Quantities						Unit Prices		Total Cost
Main	ID	Detailed	Running line [km]	Basis	Key assum.	Estimate value	Unit	Assumptions	Estimate value [MNOK/unit]	Unit	(deterministic value) [MNOK]
Tunnel (without superstructure)	1.1	Per lenght - Single track	72	60	20 %	72	km	Includes soiltunnels and longer portals.	75	MNOK/km	5 400
	1.2	Per lenght - Single track - parallelle				0	km		-	-	-
	1.3	Per lenght - Single track - poor rock conditions				0	km		-	-	-
	1.4	Per lenght - Double track				0	km		-	-	-
	1.5	Special tunnels (Single track) along the hillside				0	km		-		-
	1.6	Fixed (pr. sites)				25	Sites		20	MNOK/site	500
	1.7	Fixed (pr. sites) - virgin area				0	Sites		-	-	-
	1.8	Addition for service tunnel				60	km	For tunnels longer than 800 m.	35	MNOK/km	2 100
	1.9	Addition for passing loops in tunnel				10	km	Major part of crossing section in Solemedalen is in tunnel, elsewhere none. Assume 0.8 crossing sections in tunnel.	40	MNOK/km	400
	1.10	Addition for soil tunnels and longer portals - Single track				2	km	Cut&cover tunnels + portal structures.	60	MNOK/km	120
	1.11	Addition for soil tunnels and longer portals - Double track				0	km		-	-	-
	1.12	Special underground sites for long distance tunnels				0	Sites		-	-	-
	1.13	Special complex underground sites for long distance tunnels				0	Sites		-	-	-
	1.14	Addition for subsea tunnel				0	km		-	-	-
Open line	2.1	New open line sections, even terrain - Single track	284			284	km	Includes fences and drainage, frost insulation, landscaping and minor waterway crossings. Smaller wildlife crossing. Protection measures for integrity of the line.	20	MNOK/km	5 670
	2.2	New open line sections, even terrain - Double track				0	km	Includes fences and drainage, frost insulation, landscaping and minor waterway crossings. Smaller wildlife crossing. Protection measures for integrity of the line.	-	-	-
	2.3	Junctions/Links to existing lines				0	km		-	-	-
	2.4	Additons for proximity to existing lines (Oslo - Bergen, Hallingdal)				0	km		-	-	-
	2.6	Additons for proximity to existing lines (Oslo - Bergen, Numedal)				0	km		-	-	-
	2.7	Addition for silt soil			25 %	71	km	25 % of total running line, Outside fill areas	15	MNOK/km	1 063
	2.8	Addition for soft soil - Single track			17 %	48	km	17% of total running line	25	MNOK/km	1 205
	2.9	Addition for soft soil - Double track				0	km		-	-	-
	2.10	Addition for low cuts/fills - Single track			50 %	142	km	50 % of total running line. Less than 5 m, average 4 m	15	MNOK/km	2 126
	2.11	Addition for low cuts/fills - Double track				0	km		-	-	-
	2.12	Addition for high cuts/fills - Single track			20 %	57	km	20 % of total running line. Larger than 5 m, average 10 m	30	MNOK/km	1 701
	2.13	Addition for high cuts/fills - Double track				0	km		-	-	-
Constructions	3.1	Wildlife crossings - Single track		284	2	142	nr of const.	1 per 2 km.	3	MNOK/Con	354
	3.2	Wildlife crossings - Double track				0	nr of const.		-	-	-
	3.3	Road crossings including connections - Single track		284	3	95	nr of const.	1 per 3 km. Assume that wildlife crossings sometimes used as road crossings	3	MNOK/Con	236
	3.4	Road crossings including connections - Double track				0	nr of const.		-	-	-
	3.5	Reconstruction of local villages infrastructure				25	nr of sites		10	MNOK/Con	250
	3.6	Reconstruction of local town infrastructure				0	nr of local sites		-	-	-
	3.7	Reconstruction of local infrastructure (Oslo - Kristiansand)				0	nr of sites		-	-	-
	3.8	Railway bridges - Single track	11	7	50 %	11	km	Identified 7 km, non-identified approximately 50%.	120	MNOK/km	1 260
	3.9	Railway bridges - Double track				0	km		-	-	-
	3.10	Addition for Hardangefjord-crossing				0	nr of const.		-	-	-
	3.11	Addition for Samnangerfjord-crossing				0	nr of const.		-	-	-
	3.12	Addition for Tysnes/Stord-crossing				0	nr of const.		-	-	-
	3.13	Additions for Porsgrunnselven				0	nr of const.		-	-	-
	3.14	Additions for Topdalsfjord-crossing				0	nr of const.		-	-	-
	3.15	Additional for snow protection Hardangervidda				0	Lump sum		-	-	-
	3.16	Additional for snow protection Hardangervidda and Sangefjell				0	Lump sum		-	-	-

Uncertainty analysis

Elements			Quanties					Unit Prices (MNOK)					Total Cost
			Optimistic		Most likely	Pessimistic		Optimistic		Most likely	Pessimistic		(expected value)
ID	Description		%	Value	Value	Value	%	%	Value	Value	Value	%	[MNOK]
1.1	Tunnels Basis (without superstructure)		-24 %	55	72	100	39 %	-27 %	55	75	90	20 %	5 575
1.2	Special tunnels (Single track) along the hillside				0					0			
1.3	Tunnels Additions (without superstructure)							-32 %	2122	3120	3619	16 %	2 898
2.1	Open line Basis (without superstructure)				279			-25 %	15	20	30	50 %	6 169
2.2	Junctions/Links to existing lines									0			
2.3	Additons for proximity to existing lines									0			
2.4	Open line Poor soil additions							-50 %	1134	2268	4536	100 %	2 753
2.5	Open line Cuts/fills additions							-50 %	1914	3827	9568	150 %	5 495
3.1	Crossings (wild life and roads)							-50 %	295	591	1181	100 %	717
3.2	Reconstruction of local infrastructure							-50 %	125	250	500	100 %	304
3.3	Railway bridges		-33 %	7	11	14	33 %	-30 %	84	120	156	30 %	1 264
	Additions for special crossings									0			
	Additions for snow protection									0			

Cost estimate (deterministic/most likely)

Cost elements			Quantities						Unit Prices		Total Cost
Main	ID	Detailed	Running line	Basis	Key assum.	Estimate value	Unit	Assumptions	Estimate value	Unit	(deterministic value)
			[km]						[MNOK/unit]		[MNOK]
Superstructure	4.1	Regular line - Single track		366		366	km	Tunnels, bridges and open line.	24	MNOK/km	8 784
	4.2	Regular line - Double track				0	km		-	-	-
	4.3	Additional for passing loops				36	km	3 crossings.	21	MNOK/km	756
	4.4	Additional for slabtrack - Single track		72	90 %	65	km	Assume 90% of total length of tunnels.	7	MNOK/km	454
	4.5	Additional for slabtrack - Double track				0	km		-	-	-
Stations	5.1	Large station				0	Station		-	-	-
	5.2	Large station at Stange				1	Station	Stange, 3 tracks.	90	MNOK/station	90
	5.3	Large station at Voss				0	Station		-	-	-
	5.4	Large Station at Sarpsborg				0	Station		-	-	-
	5.5	Large station at Kongsberg				0	Station		-	-	-
	5.7	Large station at Stavanger				0	Station		-	-	-
	5.8	Large station Porsgrunn				0	Station		-	-	-
	5.9	Large station Kristiansand				0	Station		-	-	-
	5.10	Small station				2	Station	Koppang and Tynset.	20	MNOK/station	40
	5.10	Small station (Haugesund)				0	Station		-	-	-
Power supply	6.1	Power supply substations including HV-lines - Oslo - Trondheim				1			428	MNOK	428
	6.2	Power supply substations including HV-lines - Oslo - Gøteborg				0			-	-	-
	6.3	Power supply substations including HV-lines - Oslo - Bergen (Hallingdal)				0			-	-	-
	6.4	Power supply substations including HV-lines - Oslo - Bergen (Haukeli)				0			-	-	-
	6.5	Power supply substations including HV-lines - Haukeli - Stavanger				0			-	-	-
	6.7	Power supply substations including HV-lines - Oslo - Bergen (Numedal)				0			-	-	-
	6.8	Power supply substations including HV-lines - Bergen - Stavanger				0			-	-	-
	6.9	Power supply substations including HV-lines - Stavanger - Kristiansand				0			-	-	-
	6.10	Power supply substations including HV-lines - Oslo - Kristiansand				0			-	-	-
Special infrastructure	7.1	Special support Constructions infrastructure				2	sites	-	100	MNOK/site	200
Facilities	8.1	Service and maintenance facilities				2	Stations	-	20	MNOK/station	40
Contractor Costs											**33 177**
Management and Engineering	9.1	Contractor Management and Engineering				1	na	Include detailed engineering and warranties.	15 %	of Contractor Cost	4 977
	9.2	Client Management and Engineering				1	na	Preinvestigation, studies, strategies and planning. Engineering.	12 %	of Contractor Cost	3 981
Land acquisitions	10.1	Land acquisitions Oslo - Trondheim				1			2 %	of Open Line Cost	664
	10.2	Land acquisitions Oslo - Gøteborg							0 %	-	-
	10.3	Land acquisitions Oslo - Bergen							0 %	-	-
	10.4	Land acquisitions Oslo - Bergen							0 %	-	-
	10.5	Land acquisitions Haukeli - Stavanger							0 %	-	-
	10.6	Land acquisitions Oslo - Bergen							0 %	-	-
	10.7	Land acquisitions Bergen - Stavanger							0 %	-	-
	10.8	Land acquisitions Stavanger -							0 %	-	-
	10.9	Land acquisitions Oslo - Kristiansand							0 %	-	-
Project Cost			**368 km**								**42 799**
Trains and facilities	11.1	Trains				12	trains	-	112	MNOK/Train	1 344
	11.2	Maintenance facilities				1	site	-	1 920	MNOK/site	1 920
Total Investments										**MNOK**	**46 063**
										MRD	**46**

Uncertainty analysis

Elements		Quanties					Unit Prices (MNOK)					Total Cost
ID	Description	Optimistic		Most likely	Pessimistic		Optimistic		Most likely	Pessimistic		(expected value)
		%	Value	Value	Value	%	%	Value	Value	Value	%	[MNOK]
4.1	Superstructure Regular line						-25 %	6588	8784	9487	8 %	8 127
4.2	Superstructure Additions for crossings						-25 %	567	756	816	8 %	700
4.3	Superstructure Additional for slabtrack						-29 %	322	454	649	43 %	480
5.1	Stations						-23 %	100	130	200	54 %	148
6.1	Power supply						-25 %	321	428	535	25 %	427
7.1	Special support Constructions infrastructure						-50 %	100	200	500	150 %	287
8.1	Service and maintenance facilities						-10 %	36	40	44	10 %	40
Contractor Costs												**35 385**
9.1	Contractor Management and Engineering							12 %	15 %	25 %		6 400
9.2	Client Management and Engineering							8 %	12 %	16 %		4 258
10.1	Land acquisitions							0,5 %	2,0 %	3,5 %		465
Project Cost												**46 508**
11.1	Trains and facilities						-29 %	2317	3264	3754	15 %	3 071
Total Investments											**Base estimate**	**49 579**

Uncertainty Drivers	Optimistic	Most likely	Pessimistic	
	Value	Value	Value	
U1 Technological Development	0,92	0,98	1,00	
U2 Technical Requirements	0,98	1,02	1,10	
U3 Operational Concept optimisation	0,98	1,01	1,05	
U4 External Demands	0,99	1,00	1,05	
U5 Project ownership	0,90	1,00	1,20	
U6 Project management	0,88	1,00	1,12	
U7 Contractors and Materials Market	0,90	1,00	1,25	
U8 Level of planning	0,85	1,00	1,25	
			Uncertainty Drivers	**1,19**

Total estimat Oslo - Trondheim (MNOK)	**59 076**
Total estimat Oslo - Trondheim (MRD)	**59**
Standard Deviation (MRD)	**16**
Standard Deviation (%)	**27 %**

Relative uncertainty spans are similar for all corridors, except the two corridors Haukeli – Stavanger and Bergen – Stavanger with very high tunnel-shares. Uncertainty in tunnel-lengths in Haukeli – Stavanger and Bergen – Stavanger are defined as ± 5% (instead of -24 % and + 39 %). Uncertainty in unit-prices is defined as ± 27 % for Haukeli – Stavanger and -20%/+ 27 % for Bergen – Stavanger (instead of -27% and + 24 %) due to the uncertainty of the subsea-tunnel.

Appendix 3 Input: Deterministic estimate - Quantities

The following tables present the quantities used in the cost uncertainty analysis for each corridor. Note that the main cost elements Power supply and Land acquisitions are not given in the present Appendix. These elements have been assessed in separate reports, *High Speed Railway Lines in Norway - Power Supply Converter Stations including High Voltage Supply - Input to Cost Estimate*, Rev.000, dated August 21, 2007 and *Kvalitetssikring grunnerverv*, memo received august 29, 2007.

ID	Subelement	Oslo - Trondheim	Oslo - Gøteborg	Oslo - Bergen (Hallingdal)	Oslo - Bergen (Haukeli)	Haukeli - Stavanger	Oslo - Bergen (Numedal)	Bergen - Stavanger	Stavanger - Kristiansand	Kristiansand - Oslo
1.1	Per lenght - Single track	72 km	15 km	80 km	0 km	0 km	128 km	189 km	108 km	0 km
1.2	Per lenght - Single track - parallelle	0 km	0 km	37 km	0 km	0 km	37 km	0 km	0 km	0 km
1.3	Per lenght - Single track - poor rock conditions	0 km	0 km	0 km	0 km	0 km	0 km	0 km	0 km	77 km
1.4	Per lenght - Double track	0 km	0 km	0 km	246 km	119 km	0 km	0 km	0 km	0 km
1.5	Special tunnels (Single track) along the hillside	0 km	0 km	34 km	0 km	0 km	25 km	0 km	0 km	0 km
1.6	Fixed (pr. sites)	25 Sites	5 Sites	0 Sites	0 Sites	0 Sites	0 Sites	18 Sites	30 Sites	38 Sites
1.7	Fixed (pr. sites) - virgin area	0 Sites	0 Sites	60 Sites	50 Sites	20 Sites	70 Sites	0 Sites	0 Sites	0 Sites
1.8	Addition for service tunnel	60 km	15 km	68 km	0 km	0 km	116 km	40 km	80 km	36 km
1.9	Addition for passing loops in tunnel	10 km	0 km	12 km	0 km	0 km	12 km	12 km	10 km	14 km
1.10	Addition for soil tunnels and longer portals - Single track	2 km	1 km	5 km	0 km	0 km	5 km	5 km	15 km	5 km
1.11	Addition for soil tunnels and longer portals - Double track	0 km	0 km	0 km	15 km	5 km	0 km	0 km	0 km	0 km
1.12	Special underground sites for long distance tunnels	0 Sites	0 Sites	0 Sites	1 Sites	0 Sites	0 Sites	0 Sites	0 Sites	0 Sites
1.13	Special complex underground sites for long distance tunnels	0 Sites	0 Sites	0 Sites	0 Sites	4 Sites	0 Sites	4 Sites	0 Sites	0 Sites
1.14	Addition for subsea tunnel	0 km	0 km	0 km	0 km	55 km	0 km	98 km	0 km	0 km

Table 4 Quantities –Tunnel (without superstructure)

ID	Subelement	Oslo - Trondheim	Oslo - Gøteborg	Oslo - Bergen (Hallingdal)	Oslo - Bergen (Haukeli)	Haukeli - Stavanger	Oslo - Bergen (Numedal)	Bergen - Stavanger	Stavanger - Kristiansand	Kristiansand - Oslo
2.1	New open line sections, even terrain - Single track	284 km	50 km	163 km	0 km	0 km	150 km	12 km	65 km	69 km
2.2	New open line sections, even terrain - Double track	0 km	0 km	0 km	103 km	22 km	0 km	0 km	0 km	0 km
2.3	Junctions/Links to existing lines	0 km	0 km	4 Links	0 km	0 km	1 Links	0 km	0 km	0 km
2.4	Additons for proximity to existing lines (Oslo - Bergen, Hallingdal)	0 km	0 km	1 km	0 km	0 km	0 km	0 km	0 km	0 km
2.6	Additons for proximity to existing lines (Oslo - Bergen, Numedal)	0 km	0 km	0 Lump sum	0 km	0 km	1 Lump sum	0 km	0 km	0 km
2.7	Addition for silt soil	71 km	0 km	8 km	0 km	0 km	23 km	0 km	0 km	0 km
2.8	Addition for soft soil - Single track	48 km	25 km	16 km	0 km	0 km	23 km	0 km	10 km	17 km
2.9	Addition for soft soil - Double track	0 km	0 km	0 km	31 km	0 km	0 km	0 km	0 km	0 km
2.10	Addition for low cuts/fills - Single track	142 km	10 km	57 km	0 km	0 km	38 km	6 km	6 km	14 km
2.11	Addition for low cuts/fills - Double track	0 km	0 km	0 km	21 km	11 km	0 km	0 km	0 km	0 km
2.12	Addition for high cuts/fills - Single track	57 km	15 km	57 km	0 km	0 km	38 km	2 km	6 km	41 km
2.13	Addition for high cuts/fills - Double track	0 km	0 km	0 km	52 km	4 km	0 km	0 km	0 km	0 km

Table 5 Quantities – Open line

ID	Subelement	Oslo - Trondheim	Oslo - Gøteborg	Oslo - Bergen (Hallingdal)	Oslo - Bergen (Haukeli)	Haukeli - Stavanger	Oslo - Bergen (Numedal)	Bergen - Stavanger	Stavanger - Kristiansand	Kristiansand - Oslo
3.1	Wildlife crossings - Single track	142 nr of const.	30 nr of const.	82 nr of const.	0 nr of const.	0 nr of const.	75 nr of const.	0 nr of const.	15 nr of const.	23 nr of const.
3.2	Wildlife crossings - Double track	0 nr of const.	0 nr of const.	0 nr of const.	26 nr of const.	5 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.
3.3	Road crossings including connections - Single track	95 nr of const.	13 nr of const.	54 nr of const.	0 nr of const.	0 nr of const.	50 nr of const.	2 nr of const.	11 nr of const.	23 nr of const.
3.4	Road crossings including connections - Double track	0 nr of const.	0 nr of const.	0 nr of const.	26 nr of const.	5 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.
3.5	Reconstruction of local villages infrastructure	25 nr of sites	0 nr of sites	0 nr of sites	0 nr of sites	0 nr of sites	0 nr of sites	0 nr of sites	8 nr of sites	0 nr of sites
3.6	Reconstruction of local town infrastructure	nr of local 0 sites	nr of local 2 sites	nr of local 10 sites	nr of local 10 sites	nr of local 1 sites	nr of local 10 sites	nr of local 1 sites	nr of local 0 sites	nr of local 0 sites
3.7	Reconstruction of local infrastructure (Oslo - Kristiansand)	0 nr of sites	0 nr of sites	0 nr of sites	0 nr of sites	0 nr of sites	0 nr of sites	0 nr of sites	0 nr of sites	1 nr of sites
3.8	Railway bridges - Single track	11 km	5 km	24 km	0 km	0 km	24 km	20 km	21 km	17 km
3.9	Railway bridges - Double track	0 km	0 km	0 km	21 km	9 km	0 km	0 km	0 km	0 km
3.10	Addition for Hardangefjord-crossing	0 nr of const.	0 nr of const.	0 nr of const.	1 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.
3.11	Addition for Samnangerfjord-crossing	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	1 nr of const.	0 nr of const.	0 nr of const.
3.12	Addition for Tyssnes/Stord-crossing	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	1 nr of const.	0 nr of const.	0 nr of const.
3.13	Additions for Porsgrunnselven	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	1 nr of const.
3.14	Additions for Topdalsfjord-crossing	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	0 nr of const.	1 nr of const.
3.15	Additional for snow protection Hardangervidda	0 Lump sum	0 Lump sum	1 Lump sum	0 Lump sum	0 Lump sum	0 Lump sum	0 Lump sum	0 Lump sum	0 Lump sum
3.16	Additional for snow protection Hardangervidda and Sangefjell	0 Lump sum	0 Lump sum	0 Lump sum	0 Lump sum	0 Lump sum	1 Lump sum	0 Lump sum	0 Lump sum	0 Lump sum

Table 6 Quantities – Constructions

ID	Subelement	Oslo - Trondheim	Oslo - Gøteborg	Oslo - Bergen (Hallingdal)	Oslo - Bergen (Haukeli)	Haukeli - Stavanger	Oslo - Bergen (Numedal)	Bergen - Stavanger	Stavanger - Kristiansand	Kristiansand - Oslo
4.1	Regular line - Single track	366 km	70 km	338 km	0 km	0 km	364 km	319 km	194 km	162 km
4.2	Regular line - Double track	0 km	0 km	0 km	370 km	150 km	0 km	0 km	0 km	0 km
4.3	Additional for passing loops	36 km	12 km	24 km	0 km	0 km	24 km	12 km	12 km	24 km
4.4	Additional for slabtrack - Single track	65 km	0 km	136 km	0 km	0 km	171 km	268 km	97 km	58 km
4.5	Additional for slabtrack - Double track	0 km	0 km	0 km	221 km	108 km	0 km	0 km	0 km	0 km

Table 7 Quantities – Superstructure

ID	Subelement	Oslo - Trondheim	Oslo - Gøteborg	Oslo - Bergen (Hallingdal)	Oslo - Bergen (Haukeli)	Haukeli - Stavanger	Oslo - Bergen (Numedal)	Bergen - Stavanger	Stavanger - Kristiansand	Kristiansand - Oslo
5.1	Large station	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station
5.2	Large station at Stange	1 Station	0 Station	0 Station	3 Station	0 Station	0 Station	0 Station	0 Station	0 Station
5.3	Large station at Voss	0 Station	0 Station	1 Station	0 Station	0 Station	1 Station	0 Station	0 Station	0 Station
5.4	Large Station at Sarpsborg	0 Station	1 Station	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station
5.5	Large station at Kongsberg	0 Station	0 Station	0 Station	0 Station	0 Station	1 Station	0 Station	0 Station	0 Station
5.7	Large station at Stavanger	0 Station	0 Station	0 Station	0 Station	1 Station	0 Station	1 Station	0 Station	0 Station
5.8	Large station Porsgrunn	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	1 Station
5.9	Large station Kristiansand	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	1 Station
5.10	Small station	2 Station	0 Station	2 Station	3 Station	1 Station	1 Station	0 Station	1 Station	1 Station
5.10	Small station (Haugesund)	0 Station	0 Station	0 Station	0 Station	0 Station	0 Station	1 Station	0 Station	0 Station

Table 8 Quantities – Stations

ID	Subelement	Oslo - Trondheim	Oslo - Gøteborg	Oslo - Bergen (Hallingdal)	Oslo - Bergen (Haukeli)	Haukeli - Stavanger	Oslo - Bergen (Numedal)	Bergen - Stavanger	Stavanger - Kristiansand	Kristiansand - Oslo
7.1	Special support Constructions infrastructure	2 sites	0 sites	1 sites	2 sites	0 sites	2 sites	0 sites	0 sites	0 sites
8.1	Service and maintenance facilities	2 Stations	1 Stations	1 Stations	1 Stations	1 Stations	2 Stations	1 Stations	1 Stations	1 Stations
11.1	Trains	12 trains	10 trains	10 trains	10 trains	10 trains	10 trains	6 trains	6 trains	10 trains
11.2	Maintenance facilities	1 site	0 % site	20 % site	20 % site	20 % site	20 % site	10 % site	10 % site	20 % site

Table 9 Quantities – Special infrastructure, Facilities, Trains and Maintenance facilities

Appendix 4 Input: Deterministic estimate - Unit prices

The following tables present the unit prices used in the cost uncertainty analysis.

Main cost element	Subelement	ID	Unit Price	Unit	Assumption
Tunnel (without superstructure)	Per lenght - Single track	1.1	75	MNOK/km	75 m2, D&B 250.-, transport 100.-, SRF + rock bolts 9'/m, drain & invert 10'/m, heavy RS (20%x35'): 7'/m, pregrouting (20% x 400'/ 10m): 8'/m, w&fr insulation (50%x30'): 15'/m. TBM tunnel to be chosen only if economical in comparison.
	Per lenght - Single track - parallelle	1.2	75	MNOK/km	Generally more poor rock conditions. 75 m2, D&B 250.-, transport 100.-, SRF + rock bolts 12'/m, drain & invert 10'/m, heavy RS (30%x35'): 10'/m, pregrouting (30% x 400'/ 10m): 12'/m, w&fr insulation (50%x30'): 15'/m. TBM tunnel to be chosen only if economical in comparison.
	Per lenght - Single track - poor rock conditions	1.3	85	MNOK/km	Generally more poor rock conditions. 75 m2, D&B 250.-, transport 100.-, SRF + rock bolts 9'/m, drain & invert 10'/m, heavy RS (20%x35'): 7'/m, pregrouting (20% x 400'/ 10m): 8'/m, w&fr insulation (50%x30'): 15'/m. TBM tunnel to be chosen only if economical in comparison.
	Per lenght - Double track	1.4	145	MNOK/km	75 m2, D&B 250.-, transport 100.-, SRF + rock bolts 9'/m, drain & invert 10'/m, heavy RS (20%x35'): 7'/m, pregrouting (20% x 400'/ 10m): 8'/m, w&fr insulation (50%x30'): 15'/m. TBM tunnel to be chosen only if economical in comparison. Efficiency 2nd tube assumed 2/3 of the first. Add 10.000 per tube compared to single-track.
	Special tunnels (Single track) along the hillside	1.5	90	MNOK/km	Single track. Specific features like shallow tunnels, difficult construction conditions and rock burst phenomenom results in increased unit price, 10 MNOK added compared to ordinary single track. Additional 5 MNOK added due to exits.
	Fixed (pr. sites)	1.6	20	MNOK/site	Covers fixed cost independent of tunnel length. Workshop, support installation, "learning curve deficiency".
	Fixed (pr. sites) - virgin area	1.7	30	MNOK/site	Partly virgin area, 50% extra compared to Østerdalen. Covers fixed cost independent of tunnel length. Workshop, support installation, "learning curve deficiency".
	Addition for service tunnel	1.8	35	MNOK/km	35 m2, shares resources with main tunnel when good/fair rock, assume 50% of D&B and transport, 80% of rock treatment
	Addition for passing loops in tunnel	1.9	40	MNOK/km	x 2 normal tunnel (35 + 40)
	Addition for soil tunnels and longer portals - Single track	1.10	60	MNOK/km	Includes rock cut average 10 m, concrete structure, membrane, backfill & landscaping minus average rock tunnel cost.
	Addition for soil tunnels and longer portals - Double track	1.11	120	MNOK/km	Includes rock cut average 10 m, concrete structure, membrane, backfill & landscaping minus average rock tunnel cost.
	Special underground sites for long distance tunnels	1.12	50	MNOK/site	4 to 5 km access tunnels and underground plant.
	Special complex underground sites for long distance tunnels	1.13	75	MNOK/site	4 to 5 km access tunnels and complex underground plant. (Haukeli - Stavanger and Bergen - Stavanger)
	Addition for subsea tunnel	1.14	160	MNOK/km	70 MNOK/km (second tube) + 2 *45 MNOK/km (for subsea) Poor rock (on the shelf rim, tension zones with poorly compacted soil), pregrouting and more expensive lining and drainage system. Railway tunnels need expensive water control measures and higher rate of poor rock protection.

Table 10 Unit prices for tunnel cost elements

Main cost element	Subelement	ID	Unit Price	Unit	Assumption
Open line	New open line sections, even terrain - Single track	2.1	20	MNOK/km	Includes fences and drainage, frost insulation, landscaping and minor waterway crossings. Smaller wildlife crossing. Protection measures for integrity of the line. Cleaning and debris treatment of 20 m wide roadbase, average 45 m3/m a 100.- (soil replacement + embankment of which 20% by rock blasting). 2 x fence a 1000*/m, drains+cable ducts: 4000*/m, creek and minor wildlife culverts, pole foundations, gravel road, landscaping, revegetation etc.
	New open line sections, even terrain - Double track	2.2	35	MNOK/km	Includes fences and drainage, frost insulation, landscaping and minor waterway crossings. Smaller wildlife crossing. Protection measures for integrity of the line. Cleaning and debris treatment of 20 m wide roadbase, average 45 m3/m a 100.- (soil replacement + embankment of which 20% by rock blasting). 2 x fence a 1000*/m, drains+cable ducts: 4000*/m, creek and minor wildlife culverts, pole foundations, gravel road, landscaping, revegetation etc.
	Junctions/Links to existing lines	2.3	50	MNOK/Link	Unit price based on group discussions
	Additons for proximity to existing lines (Oslo Bergen, Hallingdal)	2.4	1 000	MNOK	Lump sum based on group discussions
	Additons for proximity to existing lines (Oslo Bergen, Numedal)	2.6	400	MNOK	Lump sum based on group discussions
	Addition for silt soil	2.7	15	MNOK/km	Extensive use of "imported" roadfill, geotextile, extra frost insulation and soil exchange,
	Addition for soft soil - Single track	2.8	25	MNOK/km	Ground improvement by use of LC piles or other measures, wider excavation, imported fill, surface erosion treatment, environmental care during groundwork.
	Addition for soft soil - Double track	2.9	40	MNOK/km	Ground improvement by use of LC piles or other measures, wider excavation, imported fill, surface erosion treatment, environmental care during groundwork.
	Addition for low cuts/fills - Single track	2.10	15	MNOK/km	Wider roadbase corridor,average 100 m3/m excavation/fill, of which 20% rock cuts average.
	Addition for low cuts/fills - Double track	2.11	25	MNOK/km	Wider roadbase corridor,average 100 m3/m excavation/fill, of which 20% rock cuts average.
	Addition for high cuts/fills - Single track	2.12	30	MNOK/km	Even wider roadbase, 250 m3/m excavation/fill, long transport, extensive road building and landscaping.
	Addition for high cuts/fills - Double track	2.13	60	MNOK/km	Even wider roadbase, 250 m3/m excavation/fill, long transport, extensive road building and landscaping.

Table 11 Unit prices for open line cost elements

Main cost element	Subelement	ID	Unit Price	Unit	Assumption
Constructions	Wildlife crossings - Single track	3.1	3	MNOK/Con	Net 20 m passing = 30 m structure, 80'/m + backfill & landscaping = 3 MNOK, but 20% combined with other structures.
	Wildlife crossings - Double track	3.2	5	MNOK/Con	Net 20 m passing = 30 m structure, 80'/m + backfill & landscaping = 5 MNOK, but 20% combined with other structures.
	Road crossings including connections - Single track	3.3	3	MNOK/Con	Same as wildlife crossings
	Road crossings including connections - Double track	3.4	5	MNOK/Con	Same as wildlife crossings
	Reconstruction of local villages infrastructure	3.5	10	MNOK/Con	Unit price based on group discussions
	Reconstruction of local town infrastructure	3.6	50	MNOK/Con	Unit price based on group discussions
	Reconstruction of local infrastructure (Oslo - Kristiansand)	3.7	300	MNOK/Con	Unit price based on group discussions
	Railway bridges - Single track	3.8	120	MNOK/km	Unit price based on group discussions
	Railway bridges - Double track	3.9	260	MNOK/km	Price is doubled compared to single lines, 10 % off. Mostly stable ground, foundations more costly in hillside, add 40. 1/3 of bridges in steep terrain.
	Addition for Hardangefjord-crossing	3.10	10 000	MNOK	1.8 km bridge span. Lump sum based on group discussions and memo "HØYHASTIGHETS JERNBANE I NORSK TERRENG - Noen karakteristiske trekk ved grunnforhold og topografi og tilpassede løsninger og kostnader", datert August 2007.
	Addition for Samnangerfjord-crossing	3.11	3 000	MNOK	0.8 km bridge span. Lump sum based on group discussions and memo "HØYHASTIGHETS JERNBANE I NORSK TERRENG - Noen karakteristiske trekk ved grunnforhold og topografi og tilpassede løsninger og kostnader", datert August 2007.
	Addition for Tyssnes/Stord-crossing	3.12	5 000	MNOK	1.2 km bridge span. Lump sum based on group discussions and memo "HØYHASTIGHETS JERNBANE I NORSK TERRENG - Noen karakteristiske trekk ved grunnforhold og topografi og tilpassede løsninger og kostnader", datert August 2007.
	Additions for Porsgrunnselven	3.13	400	MNOK	Lump sum based on group discussions
	Additions for Topdalsfjord-crossing	3.14	400	MNOK	Lump sum based on group discussions
	Additional for snow protection Hardangervidda	3.15	200	MNOK	10 km, viaducts. Lump sum based on group discussions
	Additional for snow protection Hardangervidda and Sangefjell	3.16	300	MNOK	Lump sum based on group discussions

Table 12 Unit prices for construction cost elements. The special construction is based on the memos presented in Appendix 8 and **Error! Reference source not found.**.

Main cost element	Subelement	ID	Unit Price	Unit	Assumption
Superstructure	Regular line - Single track	4.1	24	MNOK/km	Based on historical data from JBV. Include railway specifics like KL, signal, control, tele etc.
	Regular line - Double track	4.2	48	MNOK/km	Based on historical data from JBV. Include railway specifics like KL, signal, control, tele etc.
	Additional for passing loops	4.3	21	MNOK/km	Based on historical data from JBV. Include railway specifics like KL, signal, control, tele etc.
	Additional for slabtrack - Single track	4.4	7	MNOK/km	Based on historical data from JBV. Include railway specifics like KL, signal, control, tele etc.
	Additional for slabtrack - Double track	4.5	14	MNOK/km	Based on historical data from JBV. Include railway specifics like KL, signal, control, tele etc.

Table 13 Unit prices for superstructure cost elements

Main cost element	Subelement	ID	Unit Price	Unit	Assumption
Stations	Large station	5.1	90	MNOK/station	Three tracks. Lump sum based on group discussions
	Large station at Stange	5.2	90	MNOK/station	Three tracks. Lump sum based on group discussions
	Large station at Voss	5.3	250	MNOK/station	Unit price based on group discussions
	Large station at Sarpsborg	5.4	90	MNOK/station	Unit price based on group discussions
	Large station at Kongsberg	5.5	250	MNOK/station	Unit price based on group discussions
	Large station at Stavanger	5.7	1 000	MNOK/station	Subsurface station/Station in tunnel. Two-tracks. Comparable to Nationaltheater. Unit price based on group discussions
	Large station Porsgrunn	5.8	400	MNOK/station	Transit station. Unit price based on group discussions
	Large station Kristiansand	5.9	1 000	MNOK/station	Unit price based on group discussions
	Small station	5.10	20	MNOK/station	Unit price based on group discussions
	Small station (Haugesund)	5.10	50	MNOK/station	Unit price based on group discussions

Table 14 Unit prices for station cost elements

Main cost element	Subelement	ID	Unit Price	Unit	Assumption
Power supply	Power supply substations including HV-lines - Oslo - Trondheim	6.1	428	MNOK	Ref. document High Speed Railway Lines in Norway - Power Supply - Converter Station including High Voltage Supply - Input to Cost Estimate, rev 000.
	Power supply substations including HV-lines - Oslo - Gøteborg	6.2	50	MNOK	Ref. document High Speed Railway Lines in Norway - Power Supply - Converter Station including High Voltage Supply - Input to Cost Estimate, rev 000.
	Power supply substations including HV-lines - Oslo - Bergen (Hallingdal)	6.3	250	MNOK	Ref. document High Speed Railway Lines in Norway - Power Supply - Converter Station including High Voltage Supply - Input to Cost Estimate, rev 000.
	Power supply substations including HV-lines - Oslo - Bergen (Haukeli)	6.4	406	MNOK	Ref. document High Speed Railway Lines in Norway - Power Supply - Converter Station including High Voltage Supply - Input to Cost Estimate, rev 000.
	Power supply substations including HV-lines - Haukeli - Stavanger	6.5	122	MNOK	Ref. document High Speed Railway Lines in Norway - Power Supply - Converter Station including High Voltage Supply - Input to Cost Estimate, rev 000.
	Power supply substations including HV-lines - Oslo - Bergen (Numedal)	6.7	342	MNOK	Ref. document High Speed Railway Lines in Norway - Power Supply - Converter Station including High Voltage Supply - Input to Cost Estimate, rev 000.
	Power supply substations including HV-lines - Bergen - Stavanger	6.8	184	MNOK	Ref. document High Speed Railway Lines in Norway - Power Supply - Converter Station including High Voltage Supply - Input to Cost Estimate, rev 000.
	Power supply substations including HV-lines - Stavanger - Kristiansand	6.9	234	MNOK	Ref. document High Speed Railway Lines in Norway - Power Supply - Converter Station including High Voltage Supply - Input to Cost Estimate, rev 000.
	Power supply substations including HV-lines - Oslo - Kristiansand	6.10	184	MNOK	Ref. document High Speed Railway Lines in Norway - Power Supply - Converter Station including High Voltage Supply - Input to Cost Estimate, rev 000.

Table 15 Unit prices for power supply cost elements

Main cost element	Subelement	ID	Unit Price	Unit	Assumption
Special infrastructure	Special support Constructions infrastructure	7.1	100	MNOK/site	Unit price based on group discussions
Facilities	Service and maintenance facilities	8.1	20	MNOK/station	Unit price based on group discussions
Management and Engineering	Contractor Management and Engineering	9.1	15 %	of Contractor Cost	Based on historical data from JBV
	Client Management and Engineering	9.2	12 %	of Contractor Cost	Based on historical data from JBV

Table 16 Unit prices for special infrastructure, facilities and Mannagement & Engineering cost elements

Main cost element	Subelement	ID	Unit Price	Unit	Assumption
Land acquisitions	Land acquisitions Oslo - Trondheim	10.1	2 %	of Open Line Cost	Open Line cost includes total infrastructure investment cost less cost of tunnels, tunnels superstructure, bridges and special constructions (e.g. Hardangerfjord, Samnangerfjord and Tyssnes/Stord). Cost per m2: 10 NOK/m2, assume 1 house per km valued 2.5 MNOK. Ref. document Kvalitetssikring grunnerverv, received 29.08.2007.
	Land acquisitions Oslo - Gøteborg	10.2	8 %	of Open Line Cost	Open Line cost includes total infrastructure investment cost less cost of tunnels, tunnels superstructure, bridges and special constructions (e.g. Hardangerfjord, Samnangerfjord and Tyssnes/Stord). Cost per m2: 10 NOK/m2, assume 5 houses per km valued 2.5 MNOK. Ref. document Kvalitetssikring grunnerverv, received 29.08.2007.
	Land acquisitions Oslo - Bergen (Hallingdal)	10.3	4 %	of Open Line Cost	Open Line cost includes total infrastructure investment cost less cost of tunnels, tunnels superstructure, bridges and special constructions (e.g. Hardangerfjord, Samnangerfjord and Tyssnes/Stord). Cost per m2: 10 NOK/m2, assume 3 houses per km valued 2.5 MNOK. Ref. document Kvalitetssikring grunnerverv, received 29.08.2007.
	Land acquisitions Oslo - Bergen (Haukeli)	10.4	2 %	of Open Line Cost	Open Line cost includes total infrastructure investment cost less cost of tunnels, tunnels superstructure, bridges and special constructions (e.g. Hardangerfjord, Samnangerfjord and Tyssnes/Stord). Cost per m2: 10 NOK/m2, assume 3 houses per km valued 2.5 MNOK. Ref. document Kvalitetssikring grunnerverv, received 29.08.2007.
	Land acquisitions Haukeli - Stavanger	10.5	1 %	of Open Line Cost	Open Line cost includes total infrastructure investment cost less cost of tunnels, tunnels superstructure, bridges and special constructions (e.g. Hardangerfjord, Samnangerfjord and Tyssnes/Stord). Cost per m2: 10 NOK/m2, assume 1 house per km valued 2.5 MNOK. Ref. document Kvalitetssikring grunnerverv, received 29.08.2007.
	Land acquisitions Oslo - Bergen (Numedal)	10.6	4 %	of Open Line Cost	Open Line cost includes total infrastructure investment cost less cost of tunnels, tunnels superstructure, bridges and special constructions (e.g. Hardangerfjord, Samnangerfjord and Tyssnes/Stord). Cost per m2: 10 NOK/m2, assume 3 houses per km valued 2.5 MNOK. Ref. document Kvalitetssikring grunnerverv, received 29.08.2007.
	Land acquisitions Bergen - Stavanger	10.7	1 %	of Open Line Cost	Open Line cost includes total infrastructure investment cost less cost of tunnels, tunnels superstructure, bridges and special constructions (e.g. Hardangerfjord, Samnangerfjord and Tyssnes/Stord). Cost per m2: 10 NOK/m2, assume 1.4 houses per km valued 2.5 MNOK. Ref. document Kvalitetssikring grunnerverv, received 29.08.2007.
	Land acquisitions Stavanger - Kristiansand	10.8	3 %	of Open Line Cost	Open Line cost includes total infrastructure investment cost less cost of tunnels, tunnels superstructure, bridges and special constructions (e.g. Hardangerfjord, Samnangerfjord and Tyssnes/Stord). Cost per m2: 10 NOK/m2, assume 2 houses per km valued 2.5 MNOK. Ref. document Kvalitetssikring grunnerverv, received 29.08.2007.
	Land acquisitions Oslo - Kristiansand	10.9	3 %	of Open Line Cost	Open Line cost includes total infrastructure investment cost less cost of tunnels, tunnels superstructure, bridges and special constructions (e.g. Hardangerfjord, Samnangerfjord and Tyssnes/Stord). Cost per m2: 10 NOK/m2, assume 2 houses per km valued 2.5 MNOK. Ref. document Kvalitetssikring grunnerverv, received 29.08.2007.

Table 17 Unit prices for land acquisition cost elements

Main cost element	Subelement	ID	Unit Price	Unit	Assumption
Trains and facilities	Trains	11.1	112	MNOK/Train	TBD
	Maintenance facilities	11.2	1 920	MNOK/site	TBD

Table 18 Unit prices for trains and maintenance facilities cost elements

Table 19 Triple estimate – Crossings (Wildlife and roads), Reconstruction of local infrastructure, Railway bridges, Additions for special crossings and Additions for snow protection

			Quanties			Unit prices		
Description			**Optimistic**	**Most likely**	**Pessimistic**	**Optimistic**	**Most likely**	**Pessimistic**
Main cost element	**ID**	**Subelement**	**%**	**Value**	**%**	**%**	**Value**	**%**
Superstructure Regular line	4.1	Regular line - Single track				-25 %		8 %
	4.2	Regular line - Double track						
Superstructure Additions for crossings	4.3	Additional for passing loops				-25 %		8 %
Superstructure Additional for slabtrack	4.4	Additional for slabtrack - Single track				-29 %		43 %
	4.5	Additional for slabtrack - Double track						
Stations	5.1 -	Large and small stations				-23 %		54 %
Power supply	6.1 -	Power supply substations including HV-lines				-25 %		25 %
Special support Constructions infrastructure	7.1	Special support Constructions infrastructure				-50 %		150 %
Service and maintenance facilities	8.1	Service and maintenance facilities				-10 %		10 %

Table 20 Triple estimate – Superstructure Regular line, Superstructure additions for crossings, Superstructure additional for slabtrack, Stations, Power supply, Special support construction infrastructure and Service and maintenance facilities.

			Quanties			Unit prices		
Description			**Optimistic**	**Most likely**	**Pessimistic**	**Optimistic**	**Most likely**	**Pessimistic**
Main cost element	**ID**	**Subelement**	**%**	**Value**	**%**	**%**	**Value**	**%**
Contractor Management and Engineering	9.1	Contractor Management and Engineering				12% [1)]	15% [1)]	25% [1)]
Client Management and Engineering	9.2	Client Management and Engineering				8% [1)]	12% [1)]	16% [1)]
Land acquisitions	10.1	Land acquisitions Oslo - Trondheim				0,5% [2)]	2% [2)]	3,5% [2)]
	10.2	Land acquisitions Oslo - Gøteborg				4,5% [2)]	8% [2)]	10,5% [2)]
	10.3	Land acquisitions Oslo - Bergen (Hallingdal)				1,5% [2)]	4% [2)]	6,5% [2)]
	10.4	Land acquisitions Oslo - Bergen (Haukeli)				0,5% [2)]	2% [2)]	3,5% [2)]
	10.5	Land acquisitions Haukeli - Stavanger				0 % [2)]	1% [2)]	2,5% [2)]
	10.6	Land acquisitions Oslo - Bergen (Numedal)				1,5% [2)]	4% [2)]	6,5% [2)]
	10.7	Land acquisitions Bergen - Stavanger				0% [2)]	1% [2)]	2,5% [2)]
	10.8	Land acquisitions Stavanger - Kristiansand				1,5% [2)]	3% [2)]	4,5% [2)]
	10.9	Land acquisitions Oslo - Kristiansand				1,5% [2)]	3% [2)]	4,6% [2)]
Trains and facilities	11.1	Trains				-29 %		15 %
	11.2	Maintenance facilities						

Table 21 Triple estimate – Contractor/Client Management and Engineering, Land acquisitions and Trains and facilities[3] [4]

[3] % of total infrastructure investment cost

[4] % of open line cost. Open Line cost includes total infrastructure investment cost less cost of tunnels, tunnels superstructure, bridges and special constructions

Appendix 5 Input: Uncertainty analysis – Base cost estimate

The tables below presents the triple estimates derived for the various cost elements. Optimistic- and pessimistic estimates are given as %-change from the most likely value, except for contractor/client management/engineering and land acquisitions. These are descibed specifically in dedicated footnotes.

			Quanties			Unit prices		
Description			**Optimistic**	**Most likely**	**Pessimistic**	**Optimistic**	**Most likely**	**Pessimistic**
Main cost element	**ID**	**Subelement**	**%**	**Value**	**%**	**%**	**Value**	**%**
Tunnels Basis (without superstructure)	1.1	Per lenght - Single track	-24 %		39 %	-27 %		20 %
	1.2	Per lenght - Single track - parallelle						
	1.3	Per lenght - Single track - poor rock conditions						
	1.4	Per lenght - Double track						
Special tunnels (Single track) along the hillside	1.5	Special tunnels (Single track) along the hillside	-24 %		39 %	-27 %		20 %
Tunnels Additions (without superstructure)	1.6	Fixed (pr. sites)				-32 %		16 %
	1.7	Fixed (pr. sites) - virgin area						
	1.8	Addition for service tunnel						
	1.9	Addition for passing loops in tunnel						
	1.10	Addition for soil tunnels and longer portals - Single track						
	1.11	Addition for soil tunnels and longer portals - Double track						
	1.12	Special underground sites for long distance tunnels						
	1.13	Special complex underground sites for long distance tunnels						
	1.14	Addition for subsea tunnel						

Table 22 Triple estimate – Tunnels Basis (without superstructure), Special tunnels (single track) along the hillside and Tunnels Additions (without superstructure)

			Quanties			Unit prices		
Description			Optimistic	Most likely	Pessimistic	Optimistic	Most likely	Pessimistic
Main cost element	**ID**	**Subelement**	**%**	**Value**	**%**	**%**	**Value**	**%**
Open line Basis (without superstructure)	2.1	New open line sections, even terrain - Single track				-25 %		50 %
	2.2	New open line sections, even terrain - Double track						
Junctions/Links to existing lines	2.3	Junctions/Links to existing lines				-25 %		50 %
Additons for proximity to existing lines	2.4	Additons for proximity to existing lines (Oslo - Bergen, Hallingdal)				-25 %		50 %
	2.6	Additons for proximity to existing lines (Oslo - Bergen, Numedal)						
Open line Poor soil additions	2.7	Addition for silt soil				-50 %		100 %
	2.8	Addition for soft soil - Single track						
	2.9	Addition for soft soil - Double track						
Open line Cuts/fills additions	2.10	Addition for low cuts/fills - Single track				-50 %		150 %
	2.11	Addition for low cuts/fills - Double track						
	2.12	Addition for high cuts/fills - Single track						
	2.13	Addition for high cuts/fills - Double track						

Table 23 Triple estimate – Open Line Basis (without superstructure), Junctions/Links to existing lines, Additions for proximity to existing lines, Open line Poor soil additions and Open lne Cuts/Fills additions

			Quanties			Unit prices		
Description			Optimistic	Most likely	Pessimistic	Optimistic	Most likely	Pessimistic
Main cost element	**ID**	**Subelement**	**%**	**Value**	**%**	**%**	**Value**	**%**
Crossings (wild life and roads)	3.1	Wildlife crossings - Single track				-50 %		100 %
	3.2	Wildlife crossings - Double track						
	3.3	Road crossings including connections - Single track						
	3.4	Road crossings including connections - Double track						
Reconstruction of local infrastructure	3.5	Reconstruction of local villages infrastructure				-50 %		100 %
	3.6	Reconstruction of local town infrastructure						
	3.7	Reconstruction of local infrastructure (Oslo - Kristiansand)						
Railway bridges	3.8	Railway bridges - Single track	-33 %		33 %	-30 %		30 %
	3.9	Railway bridges - Double track						
Additions for special crossings	3.10	Addition for Hardangefjord-crossing				-40 %		100 %
	3.11	Addition for Samnangerfjord-crossing						
	3.12	Addition for Tyssnes/Stord-crossing						
	3.13	Additions for Porsgrunnselven						
	3.14	Additions for Topdalsfjord-crossing						
Additions for snow protection	3.15	Additional for snow protection Hardangervidda				-50 %		150 %
	3.16	Additional for snow protection Hardangervidda and Sangefjell						

Appendix 6 Input: Uncertainty analysis – Uncertainty drivers

The table below summaries the effect of the uncertainty drivers on the investment cost estimates. The table provides the differences compared to the corridor Oslo – Trondheim [4]. Assumptions and scenarios are described in detail in the second table below.

Corridor	**Trondheim – Oslo**	**Oslo – Gøteborg**	**Oslo – Bergen**	**Oslo – Bergen**	**Haukeli – Stavanger**	**Oslo – Bergen**	**Bergen – Stavanger**	**Stavanger – Kristiansand**	**Kristiansand – Oslo**
Via			**Hallingdal**	**Haukeli**		**Numedal**	**Directly**		**Porsgrunn**
U1 Technological Development	0.92/0.98/1.0								
U2 Technical Requirements	0.98/1.02/1.1								
U3 Operational Concept optimisation	0.98/1.01/1.05		0.93/1,01/1.10	0.93/1.01/1.10					
U4 External Demands	0.99/1.0/1.05		0.99/1.0/1.1	0.99/1.0/1.1	0.99/1.0/1.1	0.99/1.0/1.1	0.99/1.0/1.1	0.99/1.0/1.07	0.99/1.0/1.07
U5 Project Ownership	0.90/1.0/1.20								
U6 Project Management	0.88/1.0/1.12								
U7 Contractors and Materials Market	0.90/1.0/1.25								
U8 Level of planning	0.85/1.0/1.25		0.80/1.0/1.3	0.80/1.0/1.3	0.80/1.0/1.3	0.80/1.0/1.3	0.80/1.0/1.3	0.80/1.0/1.3	0.80/1.0/1.3

Table 3 Summary: Uncertainty drivers

Uncertainties	**Planning Reference**	**Best Case Scenario**	**Most Likely Scenario**	**Worst Case Scenario**
U1 Technological Development Technological development Suitability of existing train technology Technical solutions not available in time Construction technology development Assume similar for all lines,	Based on best available technology (2007) Applies to trains and infrastructure No account taken with respect to change of solutions ETCS level 2, but with cable signalling According to TSI Non-industrialised construction	All corridors: More industrialised methods for structures, like pre-cast bridges and earthworks, e.g. larger excavators supplemented by conveyers. Standardised elevated line may be used. Non-cabling signalling is a potential upside. Existing trains suitable. The following possible reductions in cost has been	All corridors: Some improvement, i.e. best case scenario. The project is likely to profit from 10 years of on-going technological development. In addition, the size of project is a technological driver itself. Value: 0.98	All corridors: No development. Value 1.0

Uncertainties	Planning Reference	Best Case Scenario	Most Likely Scenario	Worst Case Scenario
except for fjord crossings.	methods, except TBM for some of the tunnels.	identified Trondheim - Oslo: - Bridges: -50% - Open line: -15% (of open line per length and additions for poor soil and cuts/fills) - Tunnel: -20% (of tunnel length and additions) - Superstructure, innovative power supply: -2.5 MNOK/km (of total line) Total reductions of 3445 MNOK on the corridor. Value: 0.92		
U2 Technical Requirements New technical requirements during the project Maintenance concept and needs Superstructure/slab track Construction infrastructure Removal of old tracks and re-establishing the terrain Safety requirements	Based on TSI (EU standard) of today. Most parameters stable, physical parameters. TSI state that HSL shall have continuous fences, and crossings every one km, mostly comparable to Gardemobanen. Safety requirements according to TSI. Line integrity covered by TSI on a low level, e.g. must include integrity solutions not yet developed.	All corridors: Some cost reduction due to change of requirements, e.g. substitutes for slabtracks in tunnels (6 MNOK/KM x 0.9 x length tunnel = 389 MNOK). Value: 0.98	All corridors: Some cost increase due to change of requirements, e.g. extended measures for snow and integrity of the line (+ 1000 MNOK). Value: 1.02	All corridors: Major Cost increase due to change of requirements, e.g. fully lined tunnels (20 MNOK/km x length tunnel = 1440 MNOK) and extended measures integrity with respect to avalanches (1000 MNOK). Value: 1.10
U3 Operational Concept optimisation Level of speed on long lines Operational concepts Built-in flexibilitiy and capacity Connection with existing railway High speed buffer above calibrating limit Railway transportation redundancy Travel time optimisation Governing performance requirements Freight traffic/gradient High speed concept priority vs	200 to 250 kph on the new line, crossing sections 160 kph in both directions Hourly service in peak time (morning and evenings) Freight traffic by night The removal/keeping of the line Hamar Tynset is not included with respect to cost or benefits Keeping the existing line between Trondheim to Ulsberg There is a planned double track from Eidsvoll to Sørlie From Eidsvoll to Sørlie planned 200 210 kph	Corridors: - Trondheim – Oslo, - Oslo – Gøteborg, - Oslo – Bergen via Hallingdal, - Oslo – Bergen via Numedal, - Bergen - Stavanger - Oslo – Kristiansand - Kristiansand - Stavanger Some cost reduction due to investment cost optimised operational concept (i.e. removing freight traffic). Value: 0.98 Corridors: - Oslo – Bergen via Haukeli	All corridors: Some cost increase due to e.g. Life Cycle Cost optimised concept (+ 500 MNOK) Value: 1.01	Corridors: - Trondheim – Oslo, - Oslo – Gøteborg, - Oslo – Bergen via Hallingdal, - Oslo – Bergen via Numedal, - Bergen - Stavanger - Oslo – Kristiansand - Kristiansand - Stavanger Major cost increase due to demand of all inclusive service, e.g. 30 min service; demands 4 additional crossings (7 in total), 2 additional stations (5 in total) and 7 additional trains.. Value: 1.05

Uncertainties	Planning Reference	Best Case Scenario	Most Likely Scenario	Worst Case Scenario
hybrid		- Haukeli - Stavanger Reducing the operational flexibility. Increasing the gradient to 30 ‰. Value: 0.93		Corridors: - Oslo – Bergen via Haukeli - Haukeli - Stavanger Less potential increase due to the already planned double-track. Value: 1.02
U4 External Demands NIMBY, social and propriatery concerns resulting in suboptimal lines Environmental and cultural heritage concerns resulting in suboptimal lines Agriculture land-use Conflicting environmental issues Demands from stakeholders Acceptance of spoil deposits	No external demands included in basic railway figures. Wildlife crossings and compensating measures added as specific items. No sub-optimising of lines due to NIMBY. (Not In My Back Yard, describes the phenomenon in which residents designate a development as inappropriate or unwanted for their local area, even if the development is clearly a benefit for many) The law requirements with respect to noise protection, cultural heritage, and eco-system apply. Water frame directive apply. Consideration of listed/protected structures/buildings in the planning phase. Comply with a normal year 2000 standard with respect to environmental impacts (establish a reasonable standard regarding wildlife, crossings, re-establish roads, visual aspects, business).	All corridors: Some cost reduction due to generally generous attitude. Value: 0.99	All corridors: All issues covered, as is. Value: 1.0	Corridors: - Trondheim – Oslo, - Oslo – Gøteborg, Major cost increase due to extensive local and wildlife opposition. Value: 1.05 Corridors: - Oslo – Bergen via Hallingdal, - Oslo – Bergen via Numedal, Major cost increases due to extensive local and wildlife opposition (Hardangervidda,) Value: 1.1 Corridors: - Oslo – Kristiansand - Kristiansand - Stavanger Due to populated areas and protected areas (Jæren). Value: 1.07 Corridors: - Oslo – Bergen via Haukeli - Haukeli - Stavanger - Bergen – Stavanger Due to major constructions crossing the fjords. Value: 1.1

Uncertainties	Planning Reference	Best Case Scenario	Most Likely Scenario	Worst Case Scenario
U5 Project Ownership Duration of the planning process System of project funding Focus on key values, not the nice-to-haves Swedish co-operation	Professional and rational decision making from owners. Assume good focus on key values, resistance on nice-to-haves. Project optimised funding system.	All corridors: Major cost reduction due to optimum stakeholder management, organisation, predictability and funding program. Value: 0.90	All corridors: As planned. Value: 1.0	All corridors: Non-optimal funding program, program deviations and owners indecisiveness. Value: 1.20
U6 Project Management Project organisation Project Management Overall Contract strategy	Relevant experience will be used, including experience from other countries. Follow optimised project schedule. Project optimised organisation and contract strategy. No particular assumptions are made with respect to project management.	All corridors: Optimised use of relevant experience in addition to optimised project schedule, organisation and contract strategy. Value: 0.88	All corridors: As planned. Value: 1.0	All corridors: Project well ahead in time, precision level in the level of planning a major uncertainty. Value: 1.12
U7 Contractors and Materials Market Shortage of materials Contractor market	The project will create its own predictable market situation. Balanced European contractors market (construction capacity is flexible). Balanced international materials marked.	All corridors: Good competition due to attractive project. Value: 0.90	All corridors: As planned. Value: 1.0	All corridors: Major shortages in contractor capacity. Project on top of the regular investments in Scandinavia (+15%). Heated world market in materials creating hiqh price and delays (+10%). Value: 1.25
U8 Level of planning Precision level in the level of planning Use and relevance of experience from other countries Cost estimation	Prefeasibility level Ref. to document basis.	Corridors: - Trondheim – Oslo, - Oslo – Gøteborg, Further planning and engineering will uncover major cost reduction. Low relevance of reference projects with positive impact. Value: 0.85 Corridors: - Oslo – Bergen via Hallingdal, - Oslo – Bergen via Numedal, - Bergen - Stavanger	All corridors: As planned. Value: 1.0	Corridors: - Trondheim – Oslo, - Oslo – Gøteborg, Further planning and engineering will uncover major unforeseen costs. Low relevance of reference projects with large negative impact. Value: 1.25 Corridors: - Oslo – Bergen via Hallingdal, - Oslo – Bergen via Numedal, - Bergen - Stavanger - Oslo – Kristiansand

Uncertainties	Planning Reference	Best Case Scenario	Most Likely Scenario	Worst Case Scenario
		- Oslo – Kristiansand - Kristiansand - Stavanger - Oslo – Bergen via Haukeli - Haukeli - Stavanger Value: 0.80		- Kristiansand - Stavanger - Oslo – Bergen via Haukeli - Haukeli - Stavanger Value: 1.30

Table 4 Details: Uncertainty drivers

Appendix 7 Input: Uncertainty analysis – Correlations

The following correlations are included in the quantitative model:

1. Tunnel additions: Because of dependence of tunnel length.
    - Tunnel length
    - Tunnels additions (without superstructure)
    - Correlation coefficient 0.5
2. Superstructure addition for passing loops: Because of price dependence.
    - Superstructure regular line
    - Superstructure additions for passing loops
    - Correlation coefficient 0.5
3. Additions for slabtrack: Because of dependence of tunnel length
    - Tunnel length
    - Additions for slabtrack
    - Correlation coefficient 0.5

Appendix 8 Memo - Høyhastighets jernbane i norsk terreng