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

Report to Jernbaneverket

Classification: None

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Analysis lead: Paul Torgersen

Co-writers: Jan Erik Eldor

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 a concept evaluation and the establishment of an investment cost estimate including uncertainty analysis of the planned new corridors in Norway. The present report comprises the section Heimdal – Sørli of the assessed high-speed railway corridor Oslo – Trondheim. The report outlines the conclusions and recommendations derived from the analysis, in addition to the methodology and approach applied.

Conclusion

The planned high-speed railway-corridor Oslo – Trondheim is founded on the use of existing and planned high-speed railway lines between Oslo and Sørli, together with building a new high-speed railway line from Sørli to Heimdal (366 km). This report only deal with the Sørli – Heimdal line.

The whole 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 concept – as a planning reference - is defined based on the objective of “ousting air traffic on the distance at lowest cost”. Travel time between Oslo and Trondheim will be 2.45 hours and with a hourly service in peak time. The high-speed railway line will not be used for freight traffic. Freight traffic will use existing lines. This gives the following key parameters and assumptions:

- The railway line is built as single-track lines with crossing sections.
- Maximum gradient of 30 ‰ is allowed. Freight traffic will reduce the maximum gradient (down to 12,5 ‰) and increase investment cost significantly.
- Design speed is 300 kph, exceptions on particular difficult parts.
- Three crossing sections of 12 km each is required with an additional crossing at Hamar/Stange station.

Investment Cost

The present investment cost estimate includes necessary infrastructure and trains. Cost basis is 2007 Norwegian kroner. Future price escalation is not included in the present analysis according to ordinary planning guidelines for large public projects in Norway. Other general assumptions is documented in chapter 2.3.

The expected investment cost (mean value) of the project is 59.2 billion kroner. High value (p90) is 80.6 billion and low value (p10) is 40.6 billion. The standard deviation is estimated to 27 percent of the mean value. The size and the repetitive character of the project actually results in reduced uncertainty because positive and negative incidents will to some extent even out.

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.

- Phase 1 includes a comparison of existing European high-speed concepts and a detailed analysis of the transport market. The aim is to evaluate the potentials for high-speed railway services in Norway and to identify the corridors with the most potential in terms of cost-benefit.
- Phase 2 includes operational- and infrastructure planning for the corridors pointed out in phase 1. The result from phase 2 will be used in cost-benefit assessments, and a conclusion will be reached on the realization of high-speed railway services in Norway.

Metier AS has been asked to facilitate a concept evaluation and the establishment of an investment cost estimate including uncertainty analysis of the planned new corridors in Norway. The present report comprises the section Heimdal – Sørli of the assessed high-speed railway corridor Oslo – Trondheim. The report outlines the conclusions and recommendations derived from the analysis, in addition to the methodology and approach applied.

1.2 Project description

The planned high-speed railway-corridor Oslo – Trondheim (486 km) consist of the following sections:

- Trondheim – Heimdal (12 km): No high-speed railway required
- Heimdal – Sørli (366 km): New high-speed railway must be built (the topic of this report)
- Sørli – Eidsvoll (ca. 38 km): New high-speed railway already planned (ref. Nasjonal Transportplan 2006-2015, September 2005)
- Eidsvoll - Oslo (ca. 70 km): Already existing High-Speed line.

Document Basis:

- Feasibility Study Concerning high-speed railway lines in Norway, Report Phase 1, 2006-12-15 [1]
- Feasibility Study Concerning High-Speed Railway Lines in Norway, WP 300: High-Speed-Railway-Specific Conditions, 2006-12-19 [2]
- Map, scale 1:250.000 [3]

1.3 Analysis Approach and Methodology

The whole 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 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.

The uncertainty analysis has been performed according to standard methodology and tools for uncertainty analysis. 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.

For detailed descriptions of approach and methodology, reference is given to Appendix 1.

2 Operational and Technical Concept - Planning reference

2.1 Operational Concept

The following superior operational concept was defined based on the objective of “ousting air traffic on the distance at lowest cost”:

Passenger transport:	Travel time: 2.45 hours Oslo – Trondheim
	Train service: Hourly service in peak time
Freight traffic:	The high-speed railway will not be used for freight traffic. Freight traffic will use existing lines on Dovrebanen and possibly Rørosbanen.

2.2 Technical Parameters and Assumptions

The operational concept gives the following technical key parameters and assumptions (deterministic estimate):

Basic Technical Concept:	The high-speed railway between Heimdal and Sørli is planned built as single-track lines with crossings section.
Technology:	Based on today’s technology
Track gradient:	Maximum gradient of 30 ‰ is allowed.
	Comment from the group: Freight traffic will reduce the maximum gradient (down to 12,5 ‰) and increase investment cost significantly, mainly due to increased line- and tunnel length. Trade-offs will be discussed in the next report.
Speed:	250 kph operational
	300 kph design speed, exceptions on particular difficult parts
Necessary crossing sections:	12 km assuming both trains slowing down (crossing speed 160), type rhomboid. Three crossing sections required. Additional crossing at Hamar/Stange station.
Tunnel size:	Size of tunnels 75 m^2
Tracks:	Open line: Traditional ballast tracks
	Tunnels: Slabtrack in long tunnels
Signaling system:	ERTMS-2 and use of GSMR and GPRS

2.3 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

3 Deterministic Investment Cost Estimate

The table below presents the deterministic investment cost estimate prepared by the multidisciplinary group during and between workshops. Details with respect to assumptions and content are given in Appendix 2. Note that the total costs provided in the below table are deterministic values.

Main cost elements	**Details**	**Total cost (MNOK) Deterministic values**
Tunnel (without superstructure)	Tunnel lenght and fixed sites. Additions for service tunnel, crossing sections in tunnels, soil tunnels and longer portals.	8 520
Open line	New open line sections. Additions for silt/soft soil and high/low cuts and fills.	11 765
Constructions	Wildlife crossings, road crossings including connections, reconstruction of local infrastructure and railway bridges.	2 101
Superstructure	Regular line. Additions for crossings and slabtrack.	9 994
Stations	Large and small stations.	130
Power supply	Power supply substations.	500
Special infrastructure	Special support constructions.	200
Facilities	Service and maintenance facilities.	40
Contractor Costs		**33 249**
Management and Engineering	Contractor/client management and engineering.	8 977
Land acquisitions	Land acquisitions	206
Project Cost		**42 433**
Trains and facilities	Trains and maintenance facilities	3 488
Total Investments		**45 921**

Table 1 Deterministic project cost estimate, not including uncertainty assessments. This estimate is input data to the uncertainty analysis.

4 Uncertainty analysis

4.1 Project characteristics

The figure below reflects the intuitive group understanding of the main characteristics of the project, e.g. in terms of clear objectives, complexity, size and so on. Each of the individual characteristics has been assigned a value of “less” (yellow) and “more” (grey). This simple exercise contributes to the subsequent analysis in terms of comparison for consistency checks.

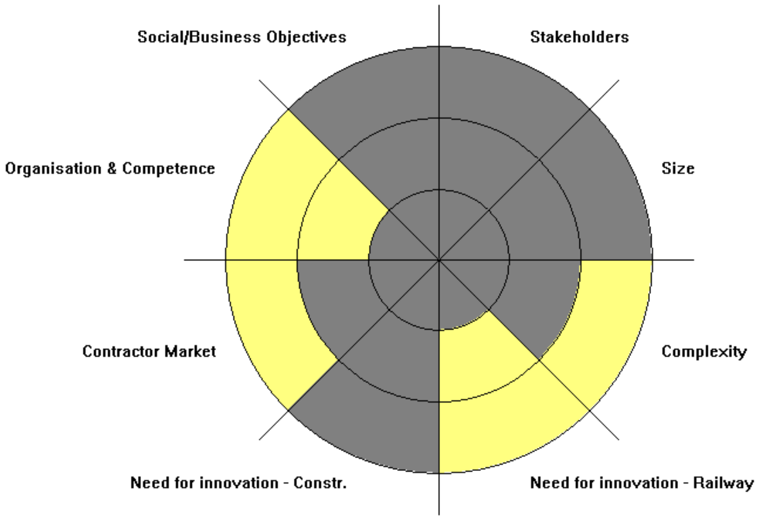

Figure 1 Project characteristics

The background for the project situation map is as follows:

Social/Business Objectives	It is recognized that superior political conditions and objectives will influence a project like this, and that expectations for financial profitability no longer are valid. The project will most likely be built on a strong political desire due to dimensions like environmentally friendliness, potential future benefits for the public and the industry and an increased attention to engineering and industrial development.
Organisation & Competence	Norway is considered to have well-established working methods and experience with respect to project management even for a project of this size. High speed railway is a high profile project and it is assumed to be attractive with respect to employment.
Contractor Market	The project will most probably be carried out with a contractor phase of five to ten years, and is large enough to significantly influence the contractor market in Scandinavia. The project will need a particular contract and market development strategy that will attract European contractors.

Stakeholders	The number of stakeholders is high and their interactions are complex. The project will attracts great political attention both regarding the interplay between air-, car- and railway transportation and the growing global environment problems. (e.g. the project may be considered a way of escaping the CO_2 problems). Attention to wildlife stakeholders may be a challenge due to the fact that the corridors run through parts of sensitive areas. There might be an increased demand from local authorities related to development of local roads and infrastructure.
Size	Compared to other railway and road investments in Norway, this project is considerable with respect to size. Railway investments amount to 1.5 - 2.5 billion Norwegian krones pr. year for the last 10 years. Road investments in Norway is about 20 billion pr. year including operations and maintenance, plus an additional about 30 billion pr. year for other heavy constructions (tunnels and groundwork) and power (Scandinavian market). The Heimdal – Sørli section is thus about the same size as the Norwegian construction marked produces in one year.
Complexity	The project and the technology are considered proven-in-use and thus not very complex. However, the complexity will increase with use of some slabtracks.
Need for innovation – Construction	The project should invent new and improved construction methods as an intensive long term development. The size of the costs and the “environmental profile” of the project demand high innovation, and therefore extensive R&D is needed.
Need for innovation – Railway	The need for innovation with respect to railway is low. Existing technology may be used. New signalling systems (use of ERMTS, GSMR and GPRS) must be approved.

4.2 Cost Estimate Uncertainty

4.2.1 Input and assessments

The uncertainty estimation model is based on the following relation:

Total Cost = Uncertainty in Base Cost Estimate • Effect of Uncertainty Drivers
+ Effect of Correlations between Cost Elements in Base Estimate

Base Cost Estimate

The base cost estimate comprises cost elements corresponding to the deterministic cost estimate (ref. 3). Each individual cost element has been assessed by the group and assigned an optimistic, most likely and pessimistic value. The triple estimates present the uncertainty related to each cost element and thus the total (aggregated) base estimate, given that the assumptions apply. The input numbers and assessments are documented in Appendix 3.

Uncertainty drivers

The uncertainty drivers are those uncertainties that can affect the entire project cost situation. The uncertainty drivers are assigned descriptions and assumptions for the base estimate (planning reference), optimistic scenario, most likely scenario and pessimistic scenario. The effect of the uncertainty drivers (scenarios) is quantified using triple estimates on factors multiplied with the base cost. The following uncertainty drivers influencing the investment costs, were identified:

- U1 Technological Development
- U2 Technical requirements
- U3 Operational Concept Optimization
- U4 External Demands
- U5 Project ownership
- U6 Project Management
- U7 Contractors and materials market
- U8 Level of planning

The input numbers and assessments are documented in Appendix 4.

Correlations between cost elements

Some inherent dependencies between cost elements are modeled as correlations. The input numbers and assessments are documented in Appendix 5.

Additional identified uncertainties

In addition there were some uncertainties identified that are addressed directly in the Base Cost Estimate. These are ground conditions and prices, topography issues, wildlife crossings, solutions for integrity of the line, overhead power systems and power supply.

There were also some uncertainties identified that are considered part of the decision basis for the project or considered part of the key assumptions. These are: development of transportation in Scandinavia, development of the freight market, general economical development, traveling market, competitive advantage railway, speed limitation for the combined freight and passenger traffic and freight traffic or not (gradient).

4.2.2 Estimate results

The table below provides a summery of the estimate results:

Deterministic estimate (sum of most likely values):	**45.9**	**MNOK**
Expected increment:	13.3	MNOK
Expected investment cost of project (mean value)	**59.2**	**MNOK**

The table below provides the mean values for the main cost elements, including the contribution from the uncertainty drivers.

Main cost elements	Details	Total cost (MNOK) Mean values
Tunnel (without superstructure)	Tunnel lenght and fixed sites. Additions for service tunnel, crossing sections in tunnels, soil tunnels and longer portals.	8 520
Open line	New open line sections. Additions for silt/soft soil and high/low cuts and fills.	14 352
Constructions	Wildlife crossings, road crossings including connections, reconstruction of local infrastructure and railway bridges.	2 282
Superstructure	Regular line. Additions for crossings and slabtrack.	9 329
Stations	Large and small stations.	147
Power supply	Power supply substations.	500
Special infrastructure	Special support constructions.	286
Facilities	Service and maintenance facilities.	40
Contractor Costs		**35 456**
Management and Engineering	Contractor/client management and engineering.	10 604
Land acquisitions	Land acquisitions	249
Project Cost		**46 309**
Trains and facilities	Trains and maintenance facilities	3 270
Total Investments		**49 580**
Uncertainty Drivers		9 613
Total Estimate		**59 192**

Table 2 Mean project cost estimate, including uncertainty assessments.

The distribution curve below presents the probability of not exceeding specific cost levels. The standard deviation of the project is 15942 MNOK, e.g. 27 % of the expected mean value. Detailed results and models are given in Appendix 3.

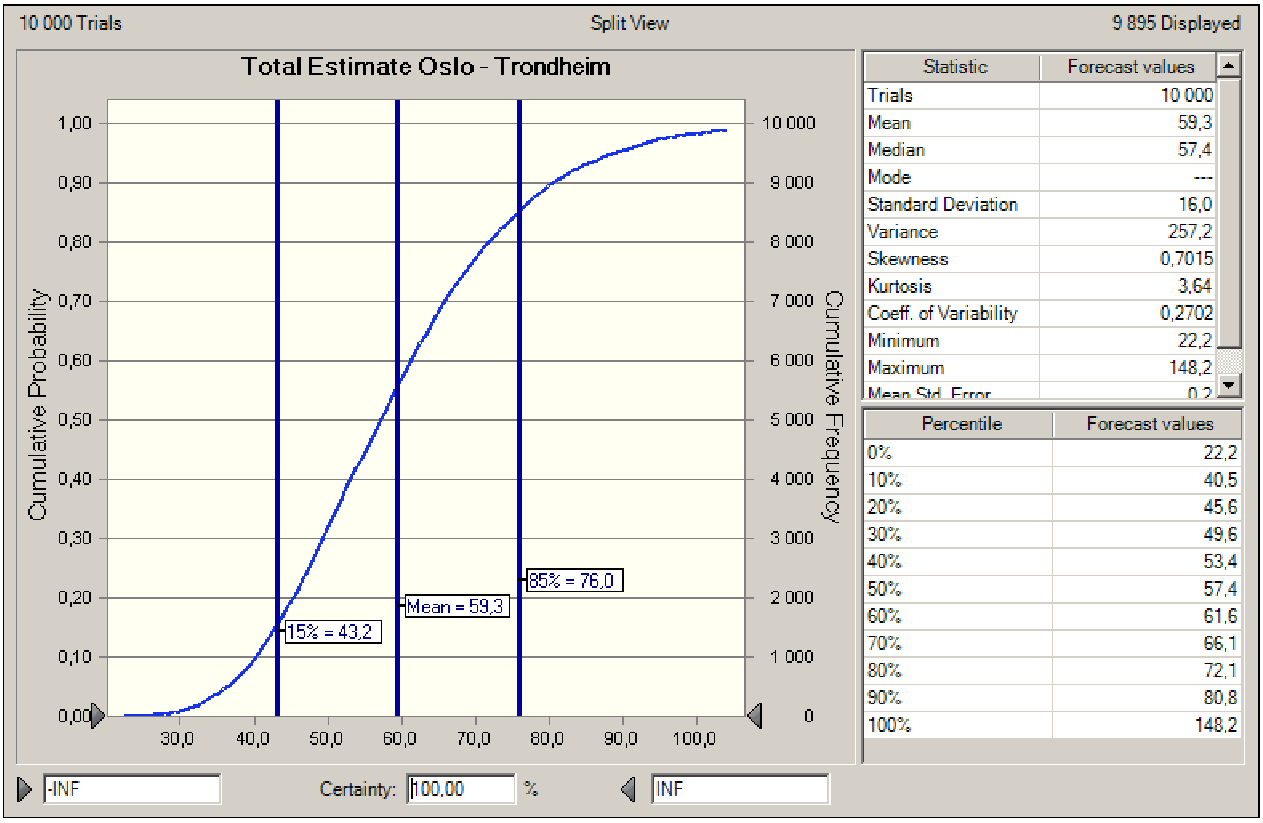

Figure 2 Cumulative distribution curve project cost (MNOK)

The uncertainty profile, represented by the figure below, illustrates the top ten uncertainties contributing the most to the total cost estimate uncertainty. The percentages represent the contribution from each cost element to the total uncertainty (which is 100 %).

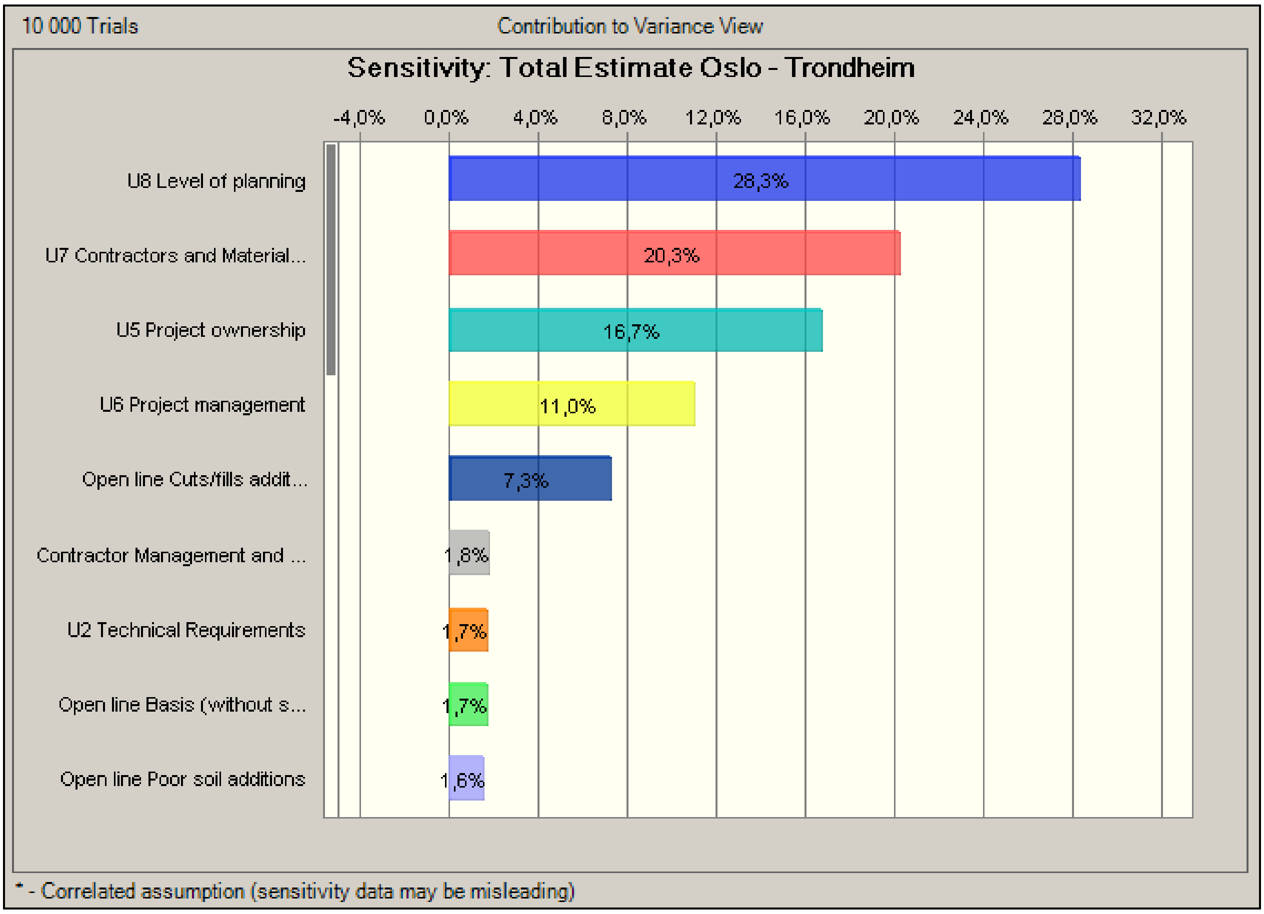

Figure 3 Uncertainty profile with respect to cost

5 Conclusion

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Appendix 1 Study approach – Details

Main approach and group meetings

The input to the concept evaluation and uncertainty analysis has been gathered in workshops with different experts. The most important workshop have been:

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

The following table presents the group-sessions participants.

			Workshops			
Name	**Role in study/Competance**	**Company**	**27.2**	**28.2**	**2.3**	**23.3**
Harry Dobeschinsky	Project-leader consultants	VWI	X	X	X	X
Peter Sautter	Alignment, costs	IGV	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		
Per Herman Sørli	Railway alignment	JBVU	X	X		X
Runar Gravdal	Costs	JBVU	X	X		X
Frode Johnsen	Energy-supply/consumption	JBV			X	
Roger Olsson	Geology	NGI	X	X		X
Anders Beitnes	Tunnel	SINTEF	X	X		X
Terje Eidsmoen	Railway	JBV	X	X		
Halstein Gåsemyr	Wheel/track	JBV	X	X		
Erik Stabell	Environmental impacts	Direktoratet for naturforvalting	X	X		
Randi Birgitte Svånå	Projectleader Jernbaneverket	Asplan Viak	X	X		X
Paul Torgersen	Facilitator Uncertainty Analysis	Metier	X	X	X	X
Jan Erik Eldor	Facilitator Uncertainty Analysis	Metier	X	X	X	X

Table 1 Contributors to the analysis (participation on workshops)

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.

Appendix 2 Deterministic estimate

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	**72**	60	20 %	**72**	km	Identified 60 km tunnel. Assumed 20% tunnel in addition. This includes soiltunnels and longer portals.	**75**	MNOK/km	**5 400**
	1.2	Fixed (pr. sites)				**25**	Sites	Assume 25 sites for all tunnels.	**20**	MNOK/site	**500**
	1.3	Addition for service tunnel				**60**	km	Includes fences and drainage, frost insulation, landscaping and minor	**35**	MNOK/km	**2 100**
	1.4	Addition for crossing sections in tunnel				**10**	km	25 % of total running line, Outside fill areas	**40**	MNOK/km	**400**
	1.5	Addition for soil tunnels and longer portals				**2**	km	17% of total running line	**60**	MNOK/km	**120**
Open line	2.1	New open line sections, even terrain	**284**			**284**	km	50 % of total running line. Less than 5 m, average 4 m	**20**	MNOK/km	**5 670**
	2.2	Addition for silt soil			25 %	**71**	km	20 % of total running line. Larger than 5 m, average 10 m	**15**	MNOK/km	**1 063**
	2.3	Addition for soft soil			17 %	**48**	km	1 per 2 km.	**25**	MNOK/km	**1 205**
	2.4	Addition for low cuts/fills			50 %	**142**	km	-	**15**	MNOK/km	**2 126**
	2.5	Addition for high cuts/fills			20 %	**57**	km	Identified 7 km, non-identified approximately 50%.	**30**	MNOK/km	**1 701**
Constructions	3.1	Wildlife crossings		284	2	**142**	nr of const.	Tunnels, bridges and open line.	**3**	MNOK/Con	**354**
	3.2	Road crossings including connections		284	3	**95**	nr of const.	3 crossings.	**3**	MNOK/Con	**236**
	3.3	Reconstruction of local infrastructure				**25**	nr of local sites	Assume 90% of total length of tunnels.	**10**	MNOK/Con	**250**
	3.4	Railway bridges	**11**	7	50 %	**11**	km	Stange, 3 tracks.	**120**	MNOK/km	**1 260**
Superstructure	4.1	Regular line		366		**366**	km	One substation every 60 km. Power	**24**	MNOK/km	**8 784**
	4.2	Additional for crossings				**36**	km	-	**21**	MNOK/km	**756**
	4.3	Additional for slabtrack		72	90 %	**65**	km	-	**7**	MNOK/km	**454**
Stations	5.1	Large station				**1**	Station		**90**	MNOK/station	**90**
	5.2	Small stations				**2**	Stations	Include detailed engineering and	**20**	MNOK/station	**40**
Power supply	6.1	Power supply substations including HV-lines				**5**	nr of subst.	Preinvestigation, studies, strategies and planning. Engineering.	**100**	MNOK/subst	**500**
	6.2	New HV lines				**0**	km	MNOK/km. Average width 50 m.	**-**		**-**
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											**33 249**
Management and Engineering	9.1	Contractor Management and Engineering							**15 %**	of Contractor Cost	**4 987**
	9.2	Client Management and Engineering							**12 %**	of Contractor Cost	**3 990**
Land acquisitions	10.1	Land acquisitions				**294**	km		**1**	MNOK/km	**206**
Project Cost											**42 433**
Trains and facilities	11.1	Trains				**14**	trains		**112**	MNOK/train	**1 568**
	11.2	Maintenance facilities				**1**	site		**1 920**	MNOK/site	**1 920**
Total Investments			**366**	**km**							**45 921**

Table 3 Project deterministic estimate and input data to the uncertainty analysis

Appendix 3 Uncertainty analysis – Base cost estimate

Uncertainty analysis - summary

The following tables present a summary of the uncertainty analysis for the corridor Oslo - Trondheim. Note that some of the cost elements are combined, e.g. ID 1.2 in the table below comprises fixed sites, addtions for service tunnels, additions for crossing sections and additions for soil tunnels and longer portals. Detailed descriptions of the estimate uncertainty and assumptions are presented subsequent to the table below.

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]
1.1	Tunnels Basis (without superstructure)	24 %	55	72	100	39 %	-27 %	55	75	90	20 %	5 610
1.2	Tunnels Additions (without superstructure)						-32 %	2120	3120	3620	16 %	2 910
2.1	Open line Basis (without superstructure)			279			-25 %	15	20	30	50 %	6 167
2.2	Open line Poor soil additions						-50 %	1134	2268	4536	100 %	2 739
2.3	Open line Cuts/fills additions						-50 %	1914	3827	9568	150 %	5 446
3.1	Crossings (wild life and roads)						-50 %	295,3	591	1181,3	100 %	719
3.2	Reconstruction of local infrastructure						-50 %	125,0	250	500,0	100 %	303
3.3	Railway bridges	33 %	7	11	14	33 %	-30 %	84	120	156	30 %	1 260
4.1	Superstructure Regular line						-25 %	6588	8784	9516	8 %	8 145
4.2	Superstructure Additions for crossings						-25 %	567	756	819	8 %	701
4.3	Superstructure Additional for slabtrack						-29 %	324	454	648	43 %	482
5.1	Stations						-23 %	100	130	200	54 %	147
6.1	Power supply						-25 %	375	500	625	25 %	500
7.1	Special support Constructions infrastructure						-50 %	100	200	500	150 %	286
8.1	Service and maintenance facilities						-10 %	36	40	44	10 %	40
Contractor Costs												**35 456**
9.1	Contractor Management and Engineering							12 %	15 %	25 %		6 362
9.2	Client Management and Engineering							8 %	12 %	16 %		4 242
10.1	Land acquisitions						-50 %	103	206	412	100 %	249
Project Cost												**46 309**
11.1	Trains and facilities						-29 %	2488	3488	4000	15 %	3 270
Total Investments											**Base estimate**	**49 580**

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 estimate	**59 192**
			Standard Deviation	**15 942**
				27 %

Table 4 Project estimate and input data to the uncertainty analysis

Cost elements – Input and assessments

The present section includes detailed descriptions of the content of the most likely estimate and assumptions in addition to agreed triple estimates derived in the group sessions.

Main Cost Element	**Tunnels Basis (without superstructure)**					
Content	1.1 Tunnels Basis (without superstructure), detailed content according to memo: *HSR Norway Basis for Cost Estimates, 2007-03-12*					
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***	
	Per lenght	72	Identified 60 km tunnel. Assumed 20% tunnel in addition. This includes soiltunnels and longer portals.	75	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.	
	Total Cost (Quantity x Unit Price, MNOK)			**5400**	**MNOK**	
Uncertainties	Level of pregrouting, amount of heavy rock etc.			Short distances the span is from 40 to 110.		
Units	KM		% Change	Unit Price (MNOK)		% Change
Triple Estimate	Optimistic	55	-24 %	Optimistic	55	-27 %
	Most likely	72		Most likely	75	
	Pessimistic	100	39 %	Pessimistic	90	20 %

Main Cost Element	Tunnels Additions (without superstructure)				
Content	1.2 Tunnel Additions, inlcuding fixed sites, service tunnels, crossing sections, soil tunnels and longer portals. Detailed content according to memo: *HSR Norway Basis for Cost Estimates, 2007-03-12*				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	Fixed (pr. sites)	25	Assume 25 sites for all tunnels.	20	Covers fixed cost independent of tunnel length. Workshop, support installation, "learning curve deficiency".
	Addition for service tunnel	60	For tunnels longer than 800 m.	35	35 m2, shares resources with main tunnel when good/fair rock, assume 50% of D&B and transport, 80% of rock treatment
	Addition for crossing sections in tunnel	10	Major part of crossing section in Soknedalen is in tunnel, elsewhere none. Assume 0.8 crossing sections in tunnel.	40	x 2 normal tunnel (35 + 40)
	Addition for soil tunnels and longer portals	2	Cut&cover tunnels + portal structures.	60	Includes rock cut average 10 m, concrete structure, membrane, backfill & landscaping minus average rock tunnel cost.
	Total Cost (Quantity x Unit Price, MNOK)			**3120**	**MNOK**
Uncertainties	Uncertainty assessed on Total Cost. Possible reductions of MNOK 1000, primarily on service tunnels. Possible increase of MNOK 500, primarily on service tunnels				

Units	KM	Total Cost (MNOK)		% Change
Triple Estimate	Optimistic	Optimistic	2120	-32 %
	Most likely	Most likely	3120	
	Pessimistic	Pessimistic	3620	16 %

Main Cost Element	Open line Basis (without superstructure)				
Content	2.1 Open line Basis (without superstructure), including new open line sections in even terrain.				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	New open line sections, even terrain	284	Includes fences and drainage, frost insulation, landscaping and minor waterway crossings. Smaller wildlife crossing. Protection measures for integrity of the line.	20	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.
	Total Cost (Quantity x Unit Price, MNOK)			**5670**	**MNOK**
Uncertainties	Uncertainty assessed on Total Cost.				

Units	KM	Total Cost (MNOK)		% Change
Triple Estimate	Optimistic	Optimistic	15	-25 %
	Most likely	Most likely	20	
	Pessimistic	Pessimistic	30	50 %

Main Cost Element	Open line					
Content	2.2 Open line poor soil additions, including silt- and soft soil					
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***		***Assumptions***
	Addition for silt soil	71	25 % of total running line, Outside fill areas	15		Extensive use of "imported" roadfill, geotextile, extra frost insulation and soil exchange,
	Addition for soft soil	48	17% of total running line	25		Ground improvement by use of LC piles or other measures, wider excavation, imported fill, surface erosion treatment, environmental care during groundwork.
	Total Cost (Quantity x Unit Price, MNOK)			**2268**		**MNOK**
Uncertainties	Uncertainty assessed on Total Cost. Possible reductions of 50 %, possible increase of 100 %.					
Units	KM			Total Cost (MNOK)		% Change
Triple Estimate	Optimistic			Optimistic	1134	-50 %
	Most likely			Most likely	2268	
	Pessimistic			Pessimistic	4536	100 %

Main Cost Element	Open line				
Content	2.3 Open line cuts/fills additions				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	Addition for low cuts/fills	142	50 % of total running line. Less than 5 m, average 4 m	15	Wider roadbase corridor,average 100 m3/m excavation/fill, of which 20% rock cuts average.
	Addition for high cuts/fills	57	20 % of total running line. Larger than 5 m, average 10 m	30	Even wider roadbase, 250 m3/m excavation/fill, long transport, extensive road building and landscaping.
	Total Cost (Quantity x Unit Price, MNOK)			**3827**	**MNOK**
Uncertainties	Uncertainty assessed on Total Cost. Possible reductions of 50 %, possible increase of 150 %.				

Units	KM	Total Cost (MNOK)		% Change
Triple Estimate	Optimistic	Optimistic	1914	-50 %
	Most likely	Most likely	3827	
	Pessimistic	Pessimistic	9568	150 %

Main Cost Element	**Constructions**				
Content	3.1 Crossings (wildlife and roads)				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	Wildlife crossings	142	1 per 2 km.	2,5	Net 20 m passing = 30 m structure, 80'/m + backfill & landscaping = 3 MNOK, but 20% combined with other structures.
	Road crossings including connections	95	1 per 3 km. Assume that wildlife crossings sometimes used as road crossings	2,5	-
	Total Cost (Quantity x Unit Price, MNOK)			**591**	**MNOK**
Uncertainties	Uncertainty assessed on Total Cost. Possible reductions of 50 % (due to lower number of crossings), possible increase of 100 % (due to higher price).				

Units	KM	Total Cost (MNOK)		% Change
Triple Estimate	Optimistic	Optimistic	295,3	-50 %
	Most likely	Most likely	590,6	
	Pessimistic	Pessimistic	1181	100 %

Main Cost Element	**Constructions**				
Content	3.2 Reconstruction of local infrastructure				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (sites)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	Reconstruction of local infrastructure	25	-	10	-
	Total Cost (Quantity x Unit Price, MNOK)			**250**	**MNOK**
Uncertainties	Uncertainty assessed on Total Cost. Possible reductions of 50 %, possible increase of 100 %.				

Units	KM		Total Cost (MNOK)		% Change
Triple Estimate	Optimistic		Optimistic	125	-50 %
	Most likely		Most likely	250	
	Pessimistic		Pessimistic	500	100 %

Main Cost Element	**Constructions**				
Content	3.3 Railway bridges				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	Railway bridges	11	Identified 7 km, non-identified approximately 50%.	120	-
	Total Cost (Quantity x Unit Price, MNOK)			**1260**	**MNOK**
Uncertainties					

Units	KM		% Change	Unit Price (MNOK)		% Change
Triple Estimate	Optimistic	7	-33 %	Optimistic	84	-30 %
	Most likely	11		Most likely	120	
	Pessimistic	14	33 %	Pessimistic	156	30 %

Main Cost Element	**Superstructure**				
Content	4.1 Superstructure Regular line				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	Regular line	366	Tunnels, bridges and open line.	24	-
	Total Cost (Quantity x Unit Price, MNOK)			**8784**	**MNOK**
Uncertainties	Uncertainty assessed on Total Cost. Possible reductions in total cost of 25 %, possible increase of 8 %. (Unit price ranging from 18 to 26 MNOK)				
Units	KM		Total Cost (MNOK)		% Change
Triple Estimate	Optimistic		Optimistic	6588	-25 %
	Most likely		Most likely	8784	
	Pessimistic		Pessimistic	9516	8 %

Main Cost Element	**Superstructure**				
Content	4.2 Superstructure additions for crossings				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	Additional for crossings	36	3 crossings.	21	-
	Total Cost (Quantity x Unit Price, MNOK)			**756**	**MNOK**
Uncertainties	Uncertainty assessed on Total Cost. Possible reductions in unit price of 25 %, possible increase of 8 %.				
Units	KM		Total Cost (MNOK)		% Change
Triple Estimate	Optimistic		Optimistic	567	-25 %
	Most likely		Most likely	756	
	Pessimistic		Pessimistic	819	8 %

Main Cost Element	Superstructure				
Content	4.3 Superstructure additional for slabtrack				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	Additional for slabtrack	65	Assume 90% of total length of tunnels.	7	-
	Total Cost (Quantity x Unit Price, MNOK)			**454**	**MNOK**
Uncertainties	Uncertainty assessed on Total Cost. Possible reductions in total cost of 29 %, possible increase of 43 %, due to unit price variations (ranging from MNOK 5 to 10).				

Units	KM	Total Cost (MNOK)		% Change
Triple Estimate	Optimistic	Optimistic	324	-29 %
	Most likely	Most likely	453,6	
	Pessimistic	Pessimistic	648	43 %

Main Cost Element	Stations				
Content	5.1 Stations, including large- and small stations				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (station)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	Large station	1	Stange, 3 tracks.	90	-
	Small stations	2	Koppang and Tynset.	20	-
	Total Cost (Quantity x Unit Price, MNOK)			**130**	**MNOK**
Uncertainties	Uncertainty assessed on Total Cost.				

Units	KM	Total Cost (MNOK)		% Change
Triple Estimate	Optimistic	Optimistic	100	-23 %
	Most likely	Most likely	130	
	Pessimistic	Pessimistic	200	54 %

Main Cost Element	Power supply					
Content	6.1 Power supply, including power supply substations					
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (stations)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***	
	Power supply substations	5	One substation every 60 km. Power supply system 15 kV, 16 2/3 Hz.	100	Each station costs MNOK 80 - 100.	
	Total Cost (Quantity x Unit Price, MNOK)			**500**	**MNOK**	
Uncertainties	Uncertainty assessed on Total Cost.					
Units	KM			Total Cost (MNOK)		% Change
Triple Estimate	Optimistic			Optimistic	375	-25 %
	Most likely			Most likely	500	
	Pessimistic			Pessimistic	625	25 %

Main Cost Element	Special support constructions infrastructure					
Content	7.1 Special support constructions infrastructure					
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (sites)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***	
	Special support Constructions infrastructure	2	-	100	-	
	Total Cost (Quantity x Unit Price, MNOK)			**200**	**MNOK**	
Uncertainties	Uncertainty assessed on Total Cost.					
Units	KM			Total Cost (MNOK)		% Change
Triple Estimate	Optimistic			Optimistic	100	-50 %
	Most likely			Most likely	200	
	Pessimistic			Pessimistic	500	150 %

Main Cost Element	**Service and maintenance facilities**				
Content	8.1 Service and maintenance facilities				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (sites)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***
	Service and maintenance facilities	2	-	20	-
	Total Cost (Quantity x Unit Price, MNOK)			**40**	**MNOK**
Uncertainties	Uncertainty assessed on Total Cost.				
Units	KM		Total Cost (MNOK)		% Change
Triple Estimate	Optimistic		Optimistic	36	-10 %
	Most likely		Most likely	40	
	Pessimistic		Pessimistic	44	10 %

Main Cost Element	**Infrastructure, planning and management**				
Content	9.1 Contractor management and engineering				
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity***	***Assumptions***	***% of Contractor cost***	***Assumptions***
	Contractor Management and Engineering	NA	NA	15 %	Include detailed engineering and warranties.
Uncertainties	Uncertainty assessed on % of contractor cost				
Units	KM		% Contractor cost		
Triple Estimate	Optimistic		Optimistic	12 %	
	Most likely		Most likely	15 %	
	Pessimistic		Pessimistic	25 %	

<table>
<tr><td>Main Cost Element</td><td colspan="5">Infrastructure, planning and management</td></tr>
<tr><td>Content</td><td colspan="5">9.2 Client management and engineering</td></tr>
<tr><td rowspan="2">Quantity- and Unit Price Estimate (most likely) and assumptions</td><td>Element</td><td>Quantity</td><td>Assumptions</td><td>% of Contractor cost</td><td>Assumptions</td></tr>
<tr><td>Client Management and Engineering</td><td>NA</td><td>NA</td><td>12 %</td><td>Preinvestigation, studies, strategies and planning. Engineering.</td></tr>
<tr><td>Uncertainties</td><td colspan="5">Uncertainty assessed on % of contractor cost</td></tr>
<tr><td>Units</td><td colspan="3">KM</td><td colspan="2">% Contractor cost</td></tr>
<tr><td>Triple Estimate</td><td colspan="3">Optimistic
Most likely
Pessimistic</td><td>Optimistic
Most likely
Pessimistic</td><td>8 %
12 %
16 %</td></tr>
</table>

Main Cost Element	**Land acquisition**					
Content	10.1 Land acquisition					
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***	
	Land acquisitions	294	MNOK/km. Average width 50 m.	0,7	Property redemption 0,3 MNOK/km, land 0,2 MNOK/km and physical compensations 0,2 MNOK/km. Average is forest of semi-good quality, NOK 10/m2.	
	Total Cost (Quantity x Unit Price, MNOK)			**206**	**MNOK**	
Uncertainties	Uncertainty assessed on Total Cost.					
Units	KM			Total Cost (MNOK)		% Change
Triple Estimate	Optimistic			Optimistic	103	-50 %
	Most likely			Most likely	206	
	Pessimistic			Pessimistic	412	100 %

Main Cost Element	**Trains and facilities**					
Content	11.1 Trains and facilities					
Quantity- and Unit Price Estimate (most likely) and assumptions	***Element***	***Quantity (km)***	***Assumptions***	***Unit Price (MNOK)***	***Assumptions***	
	Trains	14	-	112	-	
	Maintenance facilities	1	-	1920	-	
	Total Cost (Quantity x Unit Price, MNOK)			**3488**	**MNOK**	
Uncertainties	Uncertainty assessed on Total Cost.					
Units	KM			Total Cost (MNOK)		% Change
Triple Estimate	Optimistic			Optimistic	2488	-29 %
	Most likely			Most likely	3488	
	Pessimistic			Pessimistic	4000	15 %

Appendix 4 Uncertainty analysis – Uncertainty drivers

The table presents the uncertainty drivers identified, assumptions and scenarios. All values applies to the investment cost estimate.

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	Based on todays technology 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 methods, except TBM for some of the tunnels.	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 identified: 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. Value: 0.92	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	No development. Value: 1.0
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	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	Some cost increase due to change of requirements, e.g. extended measures for snow and integrity of the line (+ 1000 MNOK). Value: 1.02	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

Uncertainties	Planning Reference	Best Case Scenario	Most Likely Scenario	Worst Case Scenario
	yet developed.			
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	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	Some cost reduction due to investment cost optimised operational concept. Value: 0.98	Some cost increase due to e.g. Life Cycle Cost optimised concept (+ 500 MNOK) Value: 1.01	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. (4 x 21 + 2 x 20 + 7 x 112 = 908 MNOK). Value: 1.05
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 passings and compensating measures added as specific items. No sub-optimising of lines due to NIMBY. The law requirements with respect to noise protection, cultural heritage, and eco-system apply. Water frame directive apply. Consideration of culturally preserved objects 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).	Some cost reduction due to generally generous attitude (- 500 MNOK) Value: 0.99	All issues covered, as is. Value: 1.0	Major cost increase due to extensive local and wildlife opposition (2500 MNOK). Value: 1.05

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.	Major cost reduction due to optimum stakeholder management, organisation, predictability and funding program. Value: 0.90	As planned. Value: 1.0	Non-optimal funding program, program deviations and owners indecisiveness. Value: 1.20
U6 Project Management Project organisation Project Management Overall Contract strategy	Relevant experience from other countries will be used Follow optimised project schedule Project optimised organisation and contract strategy No particular assumptions are made with respect to project management.	Optimised use of relevant experience in addition to optimised project schedule, organisation and contract strategy. Value: 0.88	As planned. Value: 1.0	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.	Good competition due to attractive project. Value: 0.90	As planned. Value: 1.0	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.	Further planning and engineering will uncover major cost reduction. Low relevance of reference projects with positive impact. Value: 0.85	As planned. Value: 1.0	Further planning and engineering will uncover major unforeseen costs. Low relevance of reference projects with large negative impact. Value: 1.25

Appendix 5 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 crossings: Because of price dependence.
    - Superstructure regular line
    - Superstructure additions for crossings
    - Correlation coefficient 0.75
3. Additions for slabtrack: Because of dependence of tunnel length
    - Tunnel length
    - Additions for slabtrack
    - Correlation coefficient 0.5

Appendix 6 Memo Basis for cost estimates - tunnels

The present appendix comrises a memo prepared by Sintef on tunnels basis and assumptions with respect to the cost estimates for the new high-speed railway line Oslo – Trondheim. The report has not been modified by Metier.

SINTEF

MEMO

MEMO CONCERNS

HSR Norway
Basis for Cost Estimates

FOR YOUR ATTENTION | COMMENTS ARE INVITED | FOR YOUR INFORMATION | AS AGREED

SINTEF Building and Infrastructure

Address: P O Box 124 Blindern
NO-0314 Oslo
NORWAY
Location: Forskningsveien 3b
NO-0373 Oslo
Telephone: +47 22 96 55 55
Fax: +47 22 69 94 38

Enterprise No.: NO 948 007 029 MVA

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	2007-03-12		42

Background and purpose

The cost estimation comprises two phases:

1. a rational, documented and aggregated cost estimation being built upon relevant experiences and knowledge of the matter
2. a Bayesian type study of uncertainty drivers and uncertainty effects

For phase 1, when working in a group process, it is required to describe and communicate the actual items and all their content and conditions.

In this memo, some of the basic cost elements are suggested for content and governing conditions.

Tunnel (without superstructure) pos. 2.2.:

Quote: 75 m2, D&B 250.-, trasport 100.-, SRF+rock bolts 9'/m, drain&invert 10'/m, heavy RS (20%x35'): 7'/m, pregrouting (20%x400'/10m): 8'/m, w&fr insulation (50%x30'): 15'/m. TBM tunnel to be chosen only if economical in comparison.

Cost details:

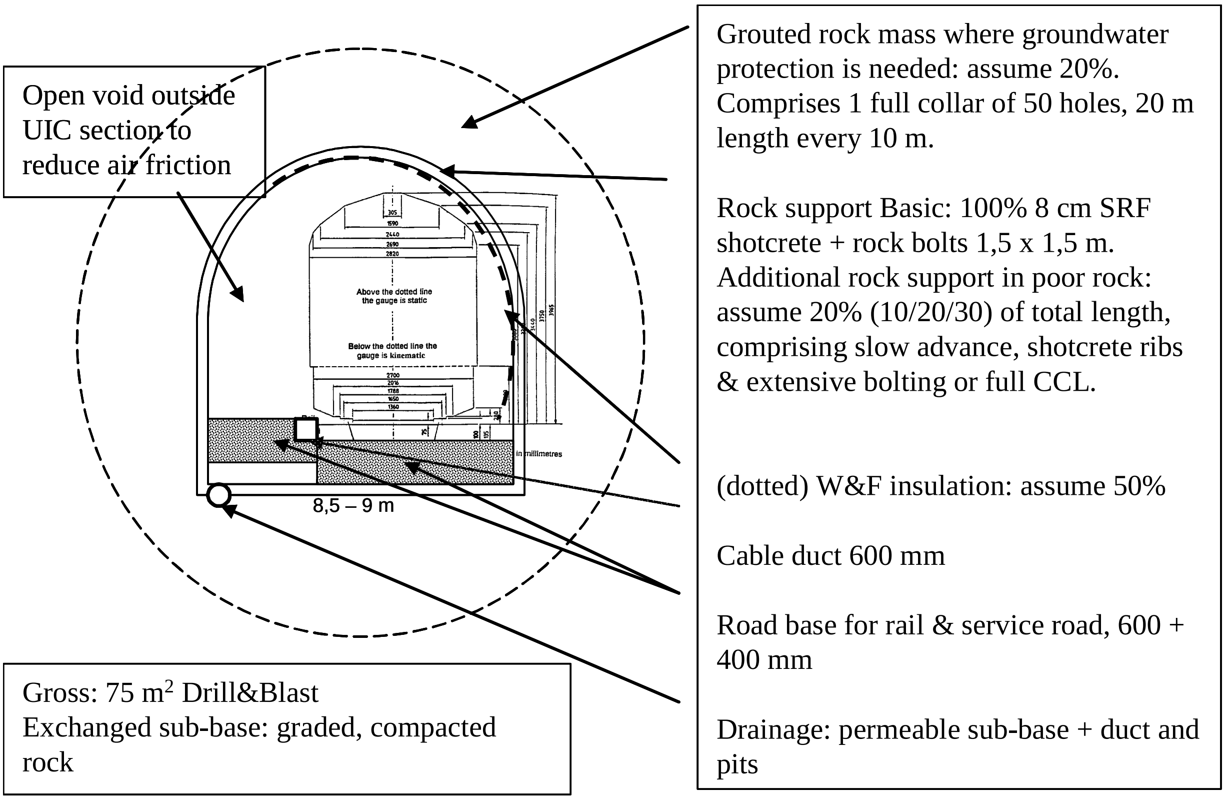
Item	Unit	Price	% of length	Low	High
Drill & blast 75 m2, incl. careful contour, rock cleaning, geol.evaluation, ditch, niches	M3 M	220:- 16.500:-	100		
Muck loading and transport, construction road in tunnel, ventilation (new requirements), transport to deposit or embankments within 2 km, drainage and sedimentation maintenance,	M3 M	100:- 7.500:-	100		
Basic rock support, considering strong demand for protection against loosening rock fragments,): full lining of min 80 mm steel fibre reinforced and fire proof shotcrete combined with rockbolts 1,5 x 1,5 m	M	9.000:-	100		
Permanent drain with pits, sub-base exchange and compaction in invert, graded roadbase for rail and super-elevated service road along the tracks, cable duct and pipelines, earth wire grid, ballast infill	M	10.000:-	100		
Additional heavy rock support in sections with poor rock conditions, fault zones and minor rock cover, comprises slow advance and excessive rock scaling, overbreak, SRF shotcrete ribs, extensive rock bolting, cast in place concrete lining in some situations	M	35.000:-	20		
Pre-grouting where groundwater protection is needed: Comprises slow advance and 1 full collar of 50 holes, 20 m length every 10 m. Average 1,5 rounds of grouting per collar.	M	40.000:-	30		
Precast concrete water & frost insulation to protect from dripping water and icicle formation (where tunnels are wet) Covers 15 m2/m	M	30.000:-	50		

Basic: 43.000.-/m

Total: 77.000:- /m

Comparison:

- Ringeriksbanen (2000): 34’ - 55’
- Romeriksporten (twin track) (1997, excl. post grouting): 55’

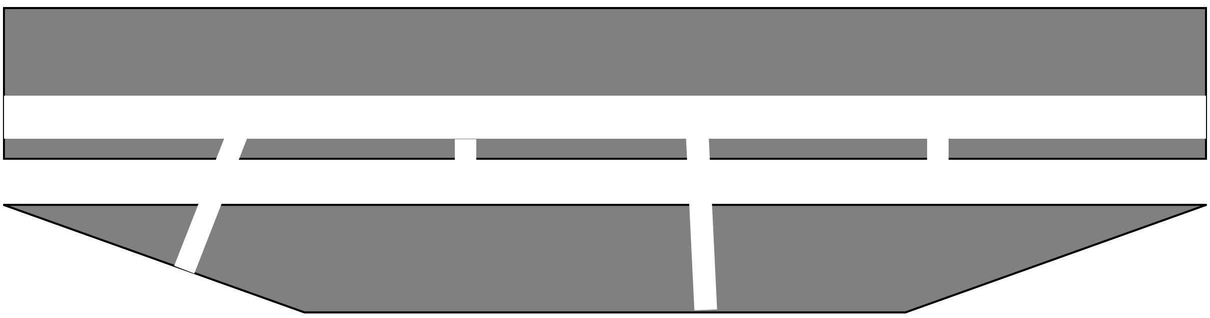


Additional cost for service tunnel; Pos 2.3

Quote: 35 m2, shares resources with main tunnel when good/fair rock, assume 50% of D&B and transp, 80% of rock treatment

Principle:

- Tunnel < 800 m. no service tunnel nor rescue access.
- Tunnel 800 – 1,5 km: One or two adit tunnels from exterior, used as access during construction.
- Tunnel > 1,5 km: Parallel service tunnel between adit tunnel positions, cross adit c/c 500 m.



Given the conditions of stiff alignment, it will often be more convenient to utilise the separate adits for construction access, as the portal areas of the main tunnel might consist of extensive earthwork and long structures.

Additional service tunnel may be approximately 35 m2 (allowing 2 trucks to pass everywhere). D&B + rock support may be 50 % of main tunnel through same rock mass. Resources per m3 are higher, volume is 50%, production conditions are favourable due to dual tunnel. Invert costs: 50%

Pre-grouting for groundwater control may be of size order 80%, as close to an equal additional amount of rock mass requires the same treatment. W&F insulation is negligible.

I.e.: Basic cost: 50% of 43' = 21.500:-

Heavy rock support & pre-grouting: = 13.000:-

Total: 34.500:-/m

Length of adits from exterior is included in costs per tunnel site.

New open line sections, even terrain, Pos 3.2

Quote: 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.

Cost details:

Item	Unit	Price	% of length	Low	High
Drill & blast rock outcrops in line, average 15 m3/m, incl. ditch	M3 M	100:- 1.500:-	20		
Cleaning of vegetation, removal and treatment of debris	M	2.000.-	70		
Average 45 m3/m excavation of and infill of graded sub-base for rail and service road, loading and transport, construction roadworks, transport to deposit or embankments within 5 km	M3 M	100:- 4.500:-	100		
Compaction in invert, graded roadbase for rail and service road along the tracks,	M	5.000:-	100		
Landscaping, care of creeks and minor wildlife, re-vegetations	M	3.000:-	100		
Fences	M	2.000:-	100		
Permanent drain with pits, cable duct and pipelines, earth wire grid, pole foundations ballast infill	M	4.000:-	100		

Total: 20.000:-/m

Addition for soft soil; Pos 3.4

Quote: Ground improvement by use of LC piles or other measures, wider excavation, imported fill, surface erosion treatment, environmental care during groundwork

Addition for high cuts/fills; Pos 3.6

Quote: Even wider roadbase, 250 m3/m excavation/fill, long transport, extensive road building and landscaping

Appendix 7 Memo Geotechnical study of selected areas