NORWAY HIGH SPEED RAIL FEASIBILITY STUDY

COST ESTIMATING AND RISK REVIEW

26TH JANUARY 2012
NORWAY HIGH SPEED RAIL FEASIBILITY STUDY

- CAPITAL COST MODEL
- LIFE CYCLE COST MODEL
- RISK REVIEW
NORWAY HIGH SPEED RAIL
- CAPITAL COST MODEL
OVERVIEW

- COST MODEL STRUCTURE
- COST ASSUMPTIONS
- CAPITAL COST MODEL (EXAMPLE)
- CAPITAL COST MODEL SPEND PROFILE
- SUMMARY OF FULL ECONOMIC APPRAISAL OPTIONS
  - COST COMPARISON BY ROUTE
  - COST PER KM
- COST DRIVERS & COMPARITORS
- MODEL VALIDATION
COST MODEL STRUCTURE

• INPUT DATA
  • Measured Quantum
  • Derived Quantum

• UNIT RATES
  • Historic Data
  • First Principals
  • Harmonization

• INDIRECT COSTS
  • Preliminaries
  • On Costs
  • Client Costs

• RISK & CONTINGENCY
  • On Cost
During the creation of this model there were a number of Key Assumptions made in defining Unit rates and Costs.

- **Generic - Common to all routes**
  - Specification – recognized Working Standard
  - On Costs – by %age addition
  - Input Data – standardized format
  - Track Alignment – agreed criteria
  - Infrastructure – linked to specification
  - Pricing – Current day prices
    - Common to all routes
    - Rates in/exclusive of

- **Route Specific**
  - Tunnels – Construction type & parameters
  - Earthworks – Band parameters
  - Structures – Type & location
    - One Offs (Specials)
  - Stations – Type/Category (Category 1 & 2 only)
  - Route - Swedish section impact
## Estimate Breakdown

### Contractor's direct costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signalling &amp; Telecoms</td>
<td>2,430,446,127</td>
<td>2.8%</td>
</tr>
<tr>
<td>Electrification &amp; Plant</td>
<td>5,164,226,260</td>
<td>6.0%</td>
</tr>
<tr>
<td>Track</td>
<td>9,264,905,751</td>
<td>10.7%</td>
</tr>
<tr>
<td>Operational Property</td>
<td>1,073,134,862</td>
<td>1.2%</td>
</tr>
<tr>
<td>Structures</td>
<td>54,706,031,331</td>
<td>63.1%</td>
</tr>
<tr>
<td>General Civils</td>
<td>12,210,323,561</td>
<td>14.1%</td>
</tr>
<tr>
<td>Utilities</td>
<td>31,587,803</td>
<td>0.0%</td>
</tr>
<tr>
<td>Depots</td>
<td>1,876,519,977</td>
<td>2.2%</td>
</tr>
</tbody>
</table>

**Sub-Total i** 86,757,174,671

### Contractor's indirect costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Preliminaries</td>
<td>17,340,697,858</td>
<td>20.0%</td>
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<tr>
<td>Design</td>
<td>4,702,425,653</td>
<td>5.4%</td>
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<tr>
<td>Testing &amp; Commissioning</td>
<td>770,260,924</td>
<td>0.9%</td>
</tr>
<tr>
<td>Training</td>
<td></td>
<td>0.0%</td>
</tr>
<tr>
<td>Spares</td>
<td></td>
<td>0.0%</td>
</tr>
<tr>
<td>Other</td>
<td>4,333,536,435</td>
<td>5.0%</td>
</tr>
</tbody>
</table>

**Sub – Total i** 27,146,920,869 31.3%

### Total Construction Cost (i+ii)

113,904,095,541

### Client's indirect and other costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client's Project Management</td>
<td>4,337,858,734</td>
<td>3.8%</td>
</tr>
<tr>
<td>Compensation charges (TOC &amp; FOC)</td>
<td>-</td>
<td>0.0%</td>
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<tr>
<td>Planning &amp; associated costs</td>
<td>2,315,130,693</td>
<td>2.0%</td>
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<tr>
<td>Land / Property Costs &amp; compensation</td>
<td>1,022,654,642</td>
<td>0.9%</td>
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</tbody>
</table>

**Sub – Total i** 7,675,644,068

### Uplift for Risk and Contingency

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Price, Design and Development Risk</td>
<td>23,775,831,757</td>
<td></td>
</tr>
</tbody>
</table>

**Project Anticipated Final Cost (AFC)** 145,355,571,366
ROUTE COST COMPARISON (1)

Total Construction Cost (mNOK)

- Indirect Costs
- Direct Costs

Construction Period (Years):
- North: 10, 8.5
- West: 7, 7
- South: 10, 6
- East: 9, 9

Costs in millions of NOK:
- Total Construction Cost: 0, 50,000, 100,000, 150,000, 200,000, 250,000

Locations:
- G3:Y
- O2:P
- N1:Q
- Ha2:P
- H1:P
- BS1:P
- S8:Q
- S2:P
- GO3:Q
- GO1:S
- ST5:U
- ST3:R
ROUTE COST COMPARISON (2)

Construction Cost per Km (mNOK)

- Construction Cost per Km
- Average Rail Data
- Average Model
During the creation of this model there were a number of Cost Drivers that have a considerable impact on final cost:

**GENERAL**
- Preliminaries
- Indirect costs assessment
- Currency conversion and parity
- Overheads and profit
- Risk Modelling

**ROUTE SPECIFIC**
- Alignment
- Geography
- Earthworks
- Tunnels
- Structures
- Stations (Category 1 & 2)

Further economic route consideration could optimize investment costs by analyzing alignment, geography and journey time relationships.
Cost Modelling Validation

Cost per Km vs Km (mNOK) Excluding Earthworks

mNOK

700
600
500
400
300
200
100
0

Distance (Km)

0 100 200 300 400 500

Northern Europe  Southern Europe  Norway HSR
<table>
<thead>
<tr>
<th>Aspect</th>
<th>EAST</th>
<th>SOUTH</th>
<th>WEST</th>
<th>NORTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnels</td>
<td>under 30%</td>
<td>av 55%</td>
<td>50 - 65%</td>
<td>40 - 60%</td>
</tr>
<tr>
<td>Alignment</td>
<td>No major issues</td>
<td>Geography dictates</td>
<td>Geography dictates</td>
<td>National Parks</td>
</tr>
<tr>
<td>Crossings</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>5/7nr Specials</td>
<td>3/4nr Specials</td>
<td>av2nr Specials</td>
<td></td>
</tr>
<tr>
<td>Earthworks</td>
<td>minimal</td>
<td>high</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Stations (nr)</td>
<td>low</td>
<td>high</td>
<td>moderate</td>
<td>moderate</td>
</tr>
</tbody>
</table>
NORWAY HIGH SPEED RAIL

- LIFE CYCLE COST MODEL
OVERVIEW

• LIFE CYCLE COST STRUCTURE & METHODOLOGY
• LIFE CYCLE COST ASSUMPTIONS & DRIVERS
• LIFE CYCLE COST BREAKDOWN
• FULL ECONOMIC APPRAISAL OPTIONS LCCS SUMMARY
• LIFE CYCLE COST SPEND PROFILE 25 YEARS
LIFE CYCLE COST STRUCTURE & METHODOLOGY

LIFE CYCLE REPLACEMENT
- Capital Cost Quantities & Unit Rates
- Service Life Expectancies
- Benchmark Percentages of Replacement
- Life Cycle Replacement Costs 25/40 years

LIFE CYCLE MAINTENANCE
- Capital Cost Quantities & Unit Rates
- Maintenance Tasks
- Labour, Vehicle & Consumable Unit Rates
- Life Cycle Maintenance Costs 25/40 years

LIFE CYCLE OPERATION
- Staff Organisation Organogram
- Annual Salaries
- Staff Numbers per Station & Train
- Life Cycle Operation Costs 25/40 years

LIFE CYCLE ROLLING STOCK LEASING COSTS
- Leasing Costs per Train Car
- Train Journey Times & Train Timetable
- Number of Trains
- Life Cycle Rolling Stock Costs 25/40 years
LIFE CYCLE COST ASSUMPTIONS & DRIVERS

- LCCs for each route in accordance with Capital Cost WBS, quantities and unit rates
- Unit rate elemental breakdown for key assets particularly M&E for Civil Work Structures
- 25/40 year LCCs from commencement of operation
- Life cycle replacement frequencies & maintenance tasks adjusted to Norwegian environment
- Staffing levels incremental & in accordance with Organogram structure
- 35 hour working week
- Allowance for shift working, w/e, holiday, training & rostering inefficiencies
- Energy cost rates & consumption figures
- Leasing costs – all-in rate including maintenance
- Cost of Sale excluded from LCCs
## LIFE CYCLE COST ESTIMATE SUMMARY

<table>
<thead>
<tr>
<th>Life Cycle Cost Estimate Breakdown</th>
<th>Total Cost Over 25 years (NOK)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Life Cycle Replacement Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signalling &amp; Telecoms</td>
<td>1,742,167,826</td>
<td>3.67%</td>
</tr>
<tr>
<td>Electrification &amp; Plant</td>
<td>138,967,331</td>
<td>0.29%</td>
</tr>
<tr>
<td>Track</td>
<td>7,004,455,666</td>
<td>14.74%</td>
</tr>
<tr>
<td>Operational Property</td>
<td>354,662,276</td>
<td>0.75%</td>
</tr>
<tr>
<td>Structures</td>
<td>5,314,637,156</td>
<td>11.18%</td>
</tr>
<tr>
<td>General Civils</td>
<td>218,326,867</td>
<td>0.46%</td>
</tr>
<tr>
<td>Depots</td>
<td>1,563,704,097</td>
<td>3.29%</td>
</tr>
<tr>
<td><strong>Sub-Total A</strong></td>
<td>16,336,921,220</td>
<td>34.38%</td>
</tr>
</tbody>
</table>

| **Life Cycle Maintenance Costs**                                       |                                 |     |
| Signalling & Telecoms                                                  | 2,201,972,819                  | 4.63% |
| Electrification & Plant                                                | 699,376,776                    | 1.47% |
| Track                                                                  | 5,201,965,631                  | 10.95%|
| Civil Engineering Works                                                | 503,026,494                    | 1.06% |
| Mechanical                                                             | 955,488,672                    | 2.01% |
| Maintenance Overheads                                                  | 111,755,376                    | 0.24% |
| **Sub-Total B**                                                        | 9,673,585,769                  | 20.36%|
**LIFE CYCLE COST ESTIMATE SUMMARY**

<table>
<thead>
<tr>
<th>Life Cycle Operating Costs</th>
<th>Total Cost</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organisation Management</td>
<td>365,289,955</td>
<td>0.77%</td>
</tr>
<tr>
<td>Operational Management</td>
<td>121,763,314</td>
<td>0.26%</td>
</tr>
<tr>
<td>Operational Staff</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning Staff</td>
<td>400,317,750</td>
<td>0.84%</td>
</tr>
<tr>
<td>Train Staff (OBS)</td>
<td>4,143,288,452</td>
<td>8.72%</td>
</tr>
<tr>
<td>Station Staff</td>
<td>2,148,371,734</td>
<td>4.52%</td>
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<tr>
<td>Exterior Train Cleaning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train Washer</td>
<td>2,548,000</td>
<td>0.01%</td>
</tr>
<tr>
<td>Shunt Driver</td>
<td>133,439,250</td>
<td>0.28%</td>
</tr>
<tr>
<td>Energy Consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructure</td>
<td>179,318,003</td>
<td>0.38%</td>
</tr>
<tr>
<td>Traction Rolling Stock</td>
<td>1,056,740,996</td>
<td>2.22%</td>
</tr>
<tr>
<td>Cost Of Sale</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Rolling Stock Leasing Costs</td>
<td>5,040,000,000</td>
<td>10.61%</td>
</tr>
</tbody>
</table>

**Sub - Total C** 13,591,077,455 28.60%

**Total Life Cycle Cost Estimate excl. on-costs (A+B+C)** 39,601,584,443 83.33%

**On Costs**
- Risk/Contingency @ 20.00% 7,920,316,889 16.67%

**Total Life Cycle Cost Estimate incl. on-costs** 47,521,901,332 100.00%

**Average Cost per annum** 1,900,876,053 4.00%
25 Year Life Cycle Cost Comparison

- Life Cycle Replacement Costs
- Life Cycle Maintenance Costs
- Life Cycle Operating Costs
- Rolling Stock Leasing Costs
- On Costs

Cost (Million NOK)

Alternative Routes:
- G3:Y
- O2:P
- N1:Q
- Ha2:P
- H1:P
- BS1:P
- S8:Q
- S2:P
- GO3:Q
- GO1:S
- ST5:U
- ST3:R
O2:P Northern Route - 25 Year Life Cycle Spend Profile

- LIFE CYCLE REPLACEMENT
- LIFE CYCLE MAINTENANCE
- LIFE CYCLE OPERATION
- ROLLING STOCK LEASING COSTS

COST (MILLION NOK)

YEAR

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
NORWAY HIGH SPEED RAIL
- RISK REVIEW
OVERVIEW

- BASIS OF RISK MODELLING
- INPUTS
- OUTPUTS & RESULTS
- EXAMPLE OF RESULTS
- ROUTE COST BREAKDOWN INCLUDING RISK
Three Areas of Risk Considered

- **Pricing**
  - Allowance for a Pricing Risk

- **Design Development**
  - Allowance for Design Development

- **Route Related**
  - Workshops to identify
    - Generic - common to all
    - Key Route Specific Risks
OUTPUTS & RESULTS

Route Related

- Generic
- Route Specific

  - Key Risks quantified
  - Quantitative Cost Risk Assessment
  - P80 Risk Output
## Risk Results

<table>
<thead>
<tr>
<th>FEA Routes</th>
<th>Base Cost</th>
<th>Pricing Risk Allowance (5%)</th>
<th>Design Risk Allowance</th>
<th>QCRA (P80)</th>
<th>Total Risk Allowance (%)</th>
<th>Anticipated Final Costs (AFC)</th>
<th>Optimism Bias (OB)</th>
<th>AFC + OB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Northern Corridor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G3:Y</td>
<td>156,378</td>
<td>7,819</td>
<td>15,638</td>
<td>5,657</td>
<td>19%</td>
<td>185,493</td>
<td>77,907</td>
<td>263,399</td>
</tr>
<tr>
<td>O2:P</td>
<td>121,580</td>
<td>6,079</td>
<td>12,158</td>
<td>5,539</td>
<td>20%</td>
<td>145,356</td>
<td>61,049</td>
<td>206,405</td>
</tr>
<tr>
<td><strong>Western Corridor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N1:Q</td>
<td>131,041</td>
<td>6,552</td>
<td>16,380</td>
<td>4,919</td>
<td>21%</td>
<td>158,893</td>
<td>65,925</td>
<td>226,717</td>
</tr>
<tr>
<td>Ha2:P</td>
<td>131,604</td>
<td>6,580</td>
<td>16,451</td>
<td>13,366</td>
<td>28%</td>
<td>168,000</td>
<td>68,499</td>
<td>235,569</td>
</tr>
<tr>
<td>H1:P</td>
<td>218,196</td>
<td>10,910</td>
<td>27,274</td>
<td>5,669</td>
<td>20%</td>
<td>262,049</td>
<td>107,440</td>
<td>369,489</td>
</tr>
<tr>
<td>BS1:P</td>
<td>94,345</td>
<td>4,717</td>
<td>11,793</td>
<td>3,852</td>
<td>22%</td>
<td>114,708</td>
<td>47,030</td>
<td>161,738</td>
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<tr>
<td><strong>Southern Corridor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S8:Q</td>
<td>185,683</td>
<td>9,284</td>
<td>18,568</td>
<td>5,343</td>
<td>18%</td>
<td>218,878</td>
<td>91,929</td>
<td>310,807</td>
</tr>
<tr>
<td>S2:R</td>
<td>189,003</td>
<td>9,450</td>
<td>18,900</td>
<td>4,706</td>
<td>17%</td>
<td>222,059</td>
<td>93,265</td>
<td>315,324</td>
</tr>
<tr>
<td><strong>Eastern Corridor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GO3:Q</td>
<td>51,458</td>
<td>2,573</td>
<td>6,432</td>
<td>5,855</td>
<td>29%</td>
<td>66,319</td>
<td>26,528</td>
<td>92,846</td>
</tr>
<tr>
<td>GO1:S</td>
<td>54,734</td>
<td>2,737</td>
<td>6,842</td>
<td>4,709</td>
<td>26%</td>
<td>69,022</td>
<td>27,609</td>
<td>96,631</td>
</tr>
<tr>
<td>ST5:U</td>
<td>106,617</td>
<td>5,331</td>
<td>13,327</td>
<td>4,052</td>
<td>21%</td>
<td>129,327</td>
<td>51,731</td>
<td>181,057</td>
</tr>
<tr>
<td>ST3:S</td>
<td>93,203</td>
<td>4,660</td>
<td>11,650</td>
<td>4,723</td>
<td>23%</td>
<td>114,236</td>
<td>45,695</td>
<td>159,931</td>
</tr>
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</table>
ALTERNATIVE ROUTE ANALYSIS
TOTAL COST BREAKDOWN

Total Construction Cost (mNOK)
## Scenario B
### Total Cost Summary

<table>
<thead>
<tr>
<th>FEA Routes</th>
<th>Base Cost</th>
<th>Price, Design and Development Risk</th>
<th>Anticipated Final Costs (AFC)</th>
<th>Total Life Cycle 25 Year Cost Estimate incl. on-costs</th>
<th>Total Life Cycle 40 Year Cost Estimate incl. on-costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Corridor</td>
<td>53,075</td>
<td>10,048</td>
<td>63,123</td>
<td>16,263</td>
<td>37,561</td>
</tr>
<tr>
<td>Western Corridor</td>
<td>28,969</td>
<td>6,494</td>
<td>35,463</td>
<td>7,434</td>
<td>19,037</td>
</tr>
<tr>
<td>Southern Corridor</td>
<td>44,852</td>
<td>7,901</td>
<td>52,753</td>
<td>11,551</td>
<td>28,088</td>
</tr>
<tr>
<td>Eastern Corridor</td>
<td>5,830</td>
<td>1,420</td>
<td>7,250</td>
<td>4,221</td>
<td>7,996</td>
</tr>
</tbody>
</table>
NORWAY HIGH SPEED RAIL

- CONCLUSIONS
CONCLUSIONS

• Capital & Life Cycle costs driven by Route Geography
  
  ➢ Tunnelling has a very large bearing
  ➢ Environmental restrictions & risks

  ➢ Northern
    • National Parks
    • Route Length

  ➢ Western
    • Special Structures
    • Route length

  ➢ Southern
    • Special Structures
    • Station Numbers

  ➢ Eastern
    • Reasonably flat terrain
    • Swedish Risk
CONCLUSIONS

• Cost Comparisons

- Total Capital Costs - Range (NoK)
  - Excluding Risk
    - From 50bn (GO3:Q) to 220bn (H1:P)
  - Including Risk
    - From 65bn (GO3:Q) to 260bn (H1:P)

- Cost per km (NoK)
  - Including Risk
    - From 245m (ST3:R) to 470m (S8:Q)

- Life Cycle Costs
  - Follow the same pattern
  - 25 year cycle
    - From 25bn (GO1:S) to 77bn (H1:P)