Jernbaneverket
Norwegian High Speed Railway Assessment Project

Contract 6: Financial & Economic Analysis
Subject 2: Estimation and Assessment of Investment Costs

Final Report

18/02/2011

Plan Design Enable

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Contract 6: Financial & Economic Analysis

Subject 2: Estimation and Assessment of Investment Costs

Final Report

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Executive Summary

Overview

This report provides the outputs of Subject 2: Estimation and Assessment of Investment Costs of the Financial and Economic Analysis contract for Jernbaneverket (JBV) assessing High Speed Rail in Norway. The primary outputs of Phase 2 of the Subject 2 workstream are the cost and risk management methodologies and models that will enable JBV to make informed decisions in Phase 3 on various High Speed Rail Route Options. It should be noted that the purpose of Phase 2 is not to present definitive costs at this stage but to provide a robust basis for future exercises.

The Cost Model identifies Capital (CAPEX) and Life Cycle Costs (OPEX) which are used in the Financial Model to enable confident decision making on route options. The models have been set up in such a way that they can cope with the identification of variations in the assumed rates and quantities. Details of the approach to risk management for CAPEX and OPEX via the use of both qualified and quantified risk assessment have also been outlined as part of this phase. The practical application of this process will be undertaken as part of Phase 3.

Capital Cost Modelling (CAPEX)

The purpose of the capital cost modelling activities undertaken in Phase 2 is to produce a robust cost model to enable the confident and informed decision making in selecting the most economically viable High Speed Rail route. There are several studies that have been considered as part this activity including the previous JBV studies, HS2 from the UK and J.P. Baumgartner percentages of capital construction cost. The latter has also be used as the basis for the establishment of the Life Cycle Cost (OPEX) model.

The methodology and associated excel based cost model will enable the comparison by route of alternative scenarios reflecting different levels of service delivery from standard intercity services to a complete new segregated High Speed routes. It should be noted that the route option specifications have not been defined in detail at this stage. However to pre-empt the requirements of Phase 3 a specification document will be provided to the Phase 3 engineering and design consultants. This specification defines what data is required from the route specification process to feed into the cost model. This detailed data will specify lengths and type of track, number and type of structures, number of crossing, passing loops and length of tunnels, for example.

It is anticipated that minor modifications to the methodology and model may be required once the specifications have been produced. The model makes assumptions regarding the basic specification of the system on such items as Permanent Way, Electrification, Signalling and Telecommunications. The base date for the cost model is 1Q2006 in accordance with JBV economic assessment guidelines. The model can include inflation up to 2011. It will be modified as part of the Phase 3 activities to produce outturn costs which will reflect inflation and other such market conditions.

The High Speed Rail Cost Model compiled consists of two cost models: an estimating cost model and a regression cost model. The first generates cost from a set of unit rates and respective quantities whilst the second resorts to historical data gathered from a number of projects of a similar nature in a similar geographic area. The former is benchmarked against the latter to verify data integrity.

The estimating model has been developed with a series of high level elemental costs for items such as route length, extent of route in tunnel, number of stations etc. To these quantities, a series of “all-in” benchmarked unit rates, derived from historical and published cost data, are applied to arrive at an overall scheme cost. The unit rate data has also been supplement by in-house historical date, client supplied data and resource led “bottom up” estimates.

The Cost Model allows the input of quantities by two methods. Firstly, as an overview at output definition stage, quantities can be determined from historical data, developed into a % of element per route km. Secondly, as the scheme develops, the quantities can be measured by element.

The Cost Model format follows a recognised standardised layout which can be used to manage cost estimates throughout the scheme development and investment cycle, from output definition to project close out.

Life Cycle Cost Modelling

The purpose of the life cycle modelling is to provide JBV with order of cost estimates for maintenance, renewals and operation in addition to the capital to ensure that the life cycle costs (LCCs) over the long-term are included as part of the overall economic assessment at this the feasibility stage. The life cycle model is an integral part of the overall JBV High Speed Rail Cost Model.

The aim is to provide a robust and workable high-level life cycle costing appraisal model that can test different high speed rail options. The LCC model has to conform to the capital cost data structure and input into the reporting requirements of the economic and financial models. For a 'dummy' run through exercise a life cycle cost analysis period of 40 years post commencement of operation was used For the Phase 3 cost modelling a life cycle period of 25 and 40 years will be provided. In addition sensitivity tests for other assessment periods, such as 60 years, could be provided if required.

The life cycle costing methodology conforms to BS ISO 15686-5:2008 Building & constructed assets - Service life planning- Part 5 and to the 'Standardized Method of Life Cycle Costing for Construction Procurement' which is a supplement to BS ISO 15686-5:2008.

The main life cycle cost headings incorporated into the model include, as items relating to construction, maintenance including replacement or refurbishment and operations.

Sources of information that have been used in the development of the life cycle methodology includes the UK HS2 data, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE PRICES AND COSTS IN THE RAILWAY SECTOR J.P. Baumgartner Professor - January 2001 and Jernbaneverket METHOD HANDBOOK JD 205 Economic analysis for Norwegian Railroad - June 2006.

Risk and Uncertainty

The primary objective in managing project risk is to identify, understand and then remove completely all risks, if it is possible to do so. Where this is not possible they should be reduced and stakeholders should be informed of the level of residual risk.

Several studies have indicated that project cost estimates tend to underestimate costs and delivery times and overestimate benefits and revenue streams. This is usually due to biases unwittingly inherent in any projects early development, and risks and uncertainties that materialise in the course of the project. This is captured in the review of actual compared to forecast costs in the Subject 4, Economic Analysis Report.

Three main stages in the life of a transport project have been identified which give an indication of the quality of risk assessment and cost estimate typical of schemes at the different stages of scheme development. The three stages are:

- Stage 1 – Pre Feasibility – minimal ability to undertake detailed risk assessment due to limited information
- Stage 2 – Option Selection – qualitative/ pseudo Quantified Risk Assessment (QRA) can be undertaken
- Stage 3 – Design development – quantified risk assessment is possible

Most scheme promoters expect a project to provide evidence that they have adopted a systematic approach to risk management. This is in essence a structured approach to identifying, assessing, and responding to risks that occur during a project. In order to adjust the base cost for the risks associated with any project, a QRA is normally conducted.

An initial “generic” High Speed Risk Register has been prepared and examples of the detailed risks to be considered during the next phase of the project are shown in Chapter 5. The Stage 2 / Stage 3 QRA activities can only commence once the route options specifications have been issued. A risk register will be completed during Phase 3 when further project details are known and it will be subject to full scrutiny, review and qualification / quantification by the overall project team at that stage.

The High Speed Cost Estimating Model offers the facility to include a risk uplift. For the ‘dummy’ run through carried out at this stage, 20% has been included as guidance only. The risk uplift at this stage is only indicative and shouldn’t be seen as a replacement of the requirement for qualitative risk assessments. It should be used and reviewed in conjunction with the uplift adjustment of 66% at this stage to account for the tendency for cost overruns in similar significant infrastructure projects as explained in the Subject 4 economic analysis report. This is known in the UK as Optimism Bias.

From the rate compilation and comparison exercises undertaken so far, it is clear that there exists the potential for a considerable range of costs dependant on the design proposals which are ultimately developed. During the preparation of this estimate a considered view has been taken as to the most suitable cost within this range, weighted in line with the anticipated scheme specification and characteristics identified from the development work undertaken to date.

Because of this and the nature of the supporting information and level of development of the Capital Cost estimates presented to date, the estimates should currently be regarded as having an average tolerance of no better than +30 to -10%, although individual elements of the estimate may exceed this.

As better data becomes available, a more sensitive estimating tolerance exercise will be undertaken.

To address the limited ability to undertake a detailed risk assessment during the pre-feasibility stage of this project, an assessment of forecast and actual costs has been undertaken as part of the Subject 4 Economic Analysis work. During the later stages of this and subsequent phases a more detailed approach to risk assessment will be adopted.

The UK Government recommended standard uplifts to be applied at each of the stages are:

- Stage 1 – Pre Feasibility – 66%
- Stage 2 – Option Selection – 40% - supplemented / considered in conjunction with QRA
- Stage 3 – Design development – 6% (superseded by QRA)

During Phase 2 and 3 a pre-feasibility level of uplift adjustment for construction costs of 66% has been assumed which is based on European guidance. This will be applied to costs that include a risk allowance determined through a QRA process which estimates the value of known risks. Full details of the recommended uplift of 66% can be seen in the Subject 4 report.

1. Introduction

1.1. Background

Jernbaneverket (JBV) has been mandated by the Norwegian Ministry of Transport and Communications to assess the issue of High Speed Rail (HSR) lines in Norway. There is a National Transport Plan covering the period from 2010-2019 which includes relatively minor enhancements to the railway network. The ministry wishes to understand if going beyond this and implementing a step change in rail service provision in the form of higher speed concepts could "contribute to obtaining socio-economically efficient and sustainable solutions for a future transport system with increased transport capacity, improved passability and accessibility".

Previous studies have been carried out looking into HSR in Norway and there are various conflicting views. The aim of this study is to provide a transparent, robust and evidence based assessment of the costs and benefits of HSR to support investment decisions.

The study has been divided into three phases.

- In Phase 1, which was completed in July 2010, the knowledge base that already existed in Norway was collated, including outputs from previous studies. This included the studies that already were conducted for the National Rail Administration and the Ministry of Transport and Communication, but also publicly available studies conducted by various stakeholders, such as Norsk bane AS, Høyhastighetsringen AS and Coinco North
- The objective of Phase 2 is to identify a common basis to be used to assess a range of possible interventions on the main rail corridors in Norway, including links to Sweden. The work in Phase 2 will use and enhance existing information, models and data. New tools will be created where existing tools are not suitable for assessing high speed rail
- In Phase 3 the tools and guiding principles established in Phase 2 will be used to test scenarios and options on the different corridors. This will provide assessments of options and enable recommendations for development and investment strategies in each corridor

This report is a component of the Phase 2 work.

The principles established in Phase 2 are to be used to test four scenarios:

- Scenario A – reference case. This is a continuation of the current railway policy and planned improvements, with relatively minor works undertaken shown in the National Transport Plan from 2010-2019. This forms the 'do minimum' scenario to which the other scenarios will be compared
- Scenario B – upgrade. A more offensive development of the current infrastructure, looking beyond the 'InterCity' area
- Scenario C – major upgrades achieving high-speed concepts. This is to be based on an aggressive upgrade of the existing network to provide a step change in journey times, and
- Scenario D – new HSR. This involves the implementation of newly built, separate HSR lines

The improvements are being considered on six corridors:

- Oslo – Bergen
- Oslo – Trondheim
- Oslo – Kristiansand and Stavanger
- Bergen – Stavanger
- Oslo – Stockholm (to Skotterud in Norway), and
- Oslo – Gothenburg (to Halden in Norway)

The scenarios will be considered in relation to the long distance travel market, for example for journeys over 100km in distance. Other studies, such as the InterCity Study will look at initiatives for shorter distance travel at a more regional level. Various route alignments, stop patterns, station designs, speed standards and fares will be tested. It will be necessary to assess conditions related to income and costs, environmental concerns, energy consumption, maintenance under winter conditions and the procurement and operational organisation of the services and infrastructure.

1.2. Overall Context of the Financial and Economic Analysis Contract

To achieve Phase 2 of the study, Jernbaneverket has commissioned 6 Contracts:

- Technical and Safety Analysis
- Rail Planning and Development
- Environmental Analysis
- Commercial and Contract Strategies
- Market Analysis, and
- Financial and Economic Analysis

WS Atkins International Ltd (Atkins) is assisting Jernbaneverket in two of the contracts: Market Analysis and Financial and Economic Analysis. This report is part of the Financial and Economic Analysis Contract.

The Financial and Economic Analysis Contract consists of five Subjects:

- Subject 1 Impact on Road and Aviation Sectors
- Subject 2 Cost Estimation
- Subject 3 Funding and Operating Structure Analysis
- Subject 4 Financial and Economic Analysis, and
- Subject 5 Uncertainty Analysis

The purpose of the Financial and Economic Analysis Contract is to establish an assessment framework to use to evaluate potential HSR options against the objectives stated in the Ministry's mandate. Outputs of the assessment framework will show the financial impact and affordability of the interventions, including an evaluation of alternative financing options. Socio-economic impacts of the improvements will also be demonstrated and together with forecast generated revenue will be considered in relation to the expected costs. The uncertainty around the results will be assessed. Together the outputs will provide a basis for HSR investment decisions in Norway.

This report provides the outputs for Subject 2 (Estimation and Assessment of Investment Costs) of the Financial and Economical Analysis Contract.

1.3. Purpose of the Estimation and Assessment of Investment Costs) Repo

The High Speed Rail Assessment Project aims to assist the Norwegian National Rail Administration (Jernbaneverket) in the decision-making process by analysing the costs and benefits of constructing a High-Speed railway in Norway. This report specifically refers to Subject 2 of the Financial and Economic Analysis Contract.

The primary purpose of the Subject 2 Workstream: Estimation and Assessment of Investment Costs, is to develop the cost and risk management methodologies and models that will enable JBV to make informed decisions at Phase 3 on various High Speed Rail Route Options. The purpose of this phase is not to prepare definitive cost estimates as the detailed route specification process has yet to begin.

The methodology and cost model developed as part of Subject 2 identifies Capital (CAPEX) and Life Cycle Costs (OPEX) which are considered necessary to input into a financial model to enable confident decision making on route options. A generic suggested approach to risk quantification and management to be adopted in the next phase for CAPEX, OPEX is discussed in Chapter 5. A specific assessment and management approach will not be defined until Phase 3 when each route option is considered. Previous studies are to be considered as part of this activity including the previous JBV studies.

The methodology and associated excel based cost models must enable the comparison by route of alternative scenarios reflecting different levels of service delivery from standard intercity services to a complete new segregated High Speed route.

1.4. Organisation of report

The report has been structured into the following Chapters:

- Chapter 2 - Assessment and Quality Assurance of Previous Estimates
- Chapter 3 – Capital Cost Modelling
- Chapter 4 – Life Cycle Cost Modelling (including Maintenance & Renewals, Operational & Occupancy costs)
- Chapter 5 – Review of Risk and Estimating Uncertainty
- Chapter 6 – Conclusions

2. Assessment and Quality Assurance of Previous Estimates

2.1. Introduction

In conjunction with preparing the Capital Cost Model Faithful + Gould carried out an assessment of a previous cost reports prepared for JBV together with those for similar projects within Northern Europe.

The results are briefly described below.

2.2. Studies reviewed

In addition to the High Speed Railway Lines in Norway: Concept Evaluation, Cost Estimate and Uncertainty Analysis Report (2007) prepared for JBV we studied further High Speed Cost Reports including:

- Nuremberg – Munich High Speed Line
- Mannheim – Stuttgart High Speed Rail
- HS1 – Channel Tunnel Rail Link
- HSL Zuid
- ICE Frankfurt – Cologne
- Hanover – Wurzburg

2.3. Key findings and recommendations

In reviewing the various cost models the first exercise was to regularise the costs to a common base date. This done the contents of each report can be aligned by the major elements (i.e. track, power, signalling and property).

Using the various published data we prepared a Regression Model, reflecting the weighted average unit rates and elemental costs. These figures were used to develop the unit rates in the F+G Cost Model and also to assess rates against the previous Cost Report prepared for JBV.

The key findings of JBV's Cost Report were:

- The Cost Model appeared incomplete as it excluded costs for Power and Signalling elements
- The level of detail was low. The figures were reported at a high level, an all inclusive rate per kilometre, without any further supporting backup. This prevented any detailed analysis of unit rates
- The Track (permanent way) base costs, having allowed for structural works (embankments, cuttings, tunnels, etc) appeared high compared to other projects and the weighted average
- It would appear that the cost estimate exercise was based on minimal data and therefore it would be fair to assess that this was a Pre-Feasibility Order of Magnitude Cost Report, and therefore any data extracted should be considered with that in mind

Further references and considerations are made of the JBV (2007) report and other cost data throughout the rest of this report.

3. Capital Cost Modelling

3.1. Introduction

3.1.1. Background to Capital Cost Modelling

The purpose of the Capital Cost Modelling is to produce a robust cost model to enable the confident and informed decision making in selecting the most economically viable High Speed Rail route.

Several studies were taken into account for the development of the High Speed Rail Cost Model. The most relevant studies are the following:

- “Concept Evaluation, Cost Estimate and Uncertainty Analysis”, Metier, Oslo, 2007
- “Comparison of High Speed Lines' CAPEX”, BSL, Hamburg, 2009
- “HS2 Cost and Risk Model”, HS2, London, 2009
- “High-Speed Rail Development Programme”, Systra and MVA Consultancy, 2009
- The Model will enable the comparison by route of alternative scenarios reflecting different levels of service delivery from standard intercity services to a complete new segregated High Speed route

3.1.2. Aims, Scope and Limitations

This report and model do not attempt to define the cost of a particular route or alignment as these will not be developed until Phase 3 of the project. The purpose is to provide a high level cost model to enable an informed financial assessment of future planned routes.

The cost model is based on delivering a high speed rail infrastructure. The detailed specifications have not been defined at this stage. These are fundamental for the creation of a solid and reliable cost model. As a result, the cost model was compiled using high level specifications compliant with European standards. The key outline specifications are:

Permanent Way:

- Standard Gauge - 1,435 mm
- Rail – CEN60 CWR
- Sleepers – Concrete, spacing of 700 mm
- Track Support – 7.5 track bed width comprised of 300 mm of bottom ballast; 300 mm of top ballast; Geotextile layer and 200 mm of sand blanket

Electrification:

- 25kV 50HZ overhead line equipment
- Auto-Transformer system

Signalling & Telecoms:

- The model can accommodate both traditional signalling and ERTMS level 2
- The system adopted for telecoms is the FTN/GSMR system

The High Speed Rail Cost Model compiled consists of two cost models: an estimating cost model and a regression cost model. The first generates cost from a set of unit rates and respective quantities whilst the second resorts to historical data gathered from a number of projects of a similar nature in a similar geographic area.

The estimating model produces the estimated cost and is then benchmarked against the regression model to verify the reliability of the resulting data.

The data is then split into different cost breakdown structures and benchmarked against data collected from different studies available to further increase the degree of reliability of the model.

Though the model offers the user a great degree of reliability, it strongly relies on the background data of both cost and specification which require updating when changes are made to either. In addition, the same applies when the total length of rail infrastructure to be built is in the region of 25 kilometres or lower as the model does not interpret skewing or distortion to the unit rates due to small quantities.

The model offers a risk uplift, however this risk uplift is indicative only and shouldn't be seen as a replacement of the requirement for qualitative risk assessments, or at an output definition stage, an optimism bias value.

3.1.3. Acknowledgements

- The base date for the cost model is 1Q2006 in accordance with JBV economic analysis guidelines. The model can include inflation up to 2011
- The currency is to be the Norwegian Kroner. The model can also express costs in Euros, USD and GBP
- The model will be used to calculate costs of different routes based on four different route options: new infrastructure, upgrade of existing infrastructure, double tracking and upgrading of existing single line and "do minimum"

3.2. Methodology

3.2.1. General

This section of the report provides a description of the methodology used in developing the CAPEX Estimate Cost Model. It will also identify and describe the data that has been and will be used in this exercise and the contents of the model.

The report will also describe our aims for this Phase and that which follows with regard to how we go about obtaining base data the sources of information that we anticipate using and how it is validated for the purposes of this model.

Finally the report will identify the current estimate tolerances.

3.2.2. Estimating Model

The estimating model has been developed using simple calculations to arrive at a series of high level elemental costs applied to quantities that can either be generated from statistical data or input manually, namely:

- The route length – based data being at Grade level
- The extent of the route being carried on elevated structures and type of structure
- The extent of the route running in cuttings and type of cutting
- The extent of the route running within tunnels and type of tunnel
- The number of stations by type
- The number of depots and sidings
- The number of grade separated and flat junctions by type
- The number of crossings between rail and roads, other rail lines and water courses

To these quantities, a series of "all-in" elemental rates have been applied to arrive at an overall scheme cost. These rates have been developed from a variety of methods but generally from first principles, benchmarked against "all-in" rates from available studies and actual costs from High Speed Rail projects in Europe. The rates from Scandinavia have subsequently been used to create a factor detail that was applied to our unit rates in order to obtain the final rates.

3.2.3. Regression Model

This exercise has also included a benchmarking estimate, resulting from processing outturn cost data of other comparable high speed rail schemes on an overall route-wide per km basis. This data from similar projects was processed and normalised to enable a logarithmic regression of the relationship between cost per route Km and total length of construction. The logarithmic regression of the Northern Europe data sets a threshold for the estimating model which, at each iteration, is benchmarked against the historical data.

In addition historical data for the proportion of cost per asset (Permanent Way, Signalling, Power, etc.) and indirect costs has been included in a number of checks. These test the model for discrepancies and errors. This greatly assists the user by displaying the expected (historical) splits against the estimating cost splits.

3.2.4. Unit Rates

The unit rates by element have been derived from historical and published cost data. We have determined bench marked rates by taking the mean of a number of similar published Northern European Inter City and High Speed Rail projects.

Generally such data can be drawn from a number of sources:

- In house historical data (From previous scheme outturn costs and estimates) at elemental or work item level
- Published data from previous schemes – country and system related, normally at elemental level
- Specific client based/supplied data
- “Bottom up” rate build-ups prepared on a resource led basis

At this stage of project development the first two categories are most relevant. Where the client has provided data this is noted in the assumptions register.

The Phase 2 unit rates reflect the considered mean Northern European rates as described above. In Phase 3, to provide further robustness, the rates will be “harmonised”. In conjunction with JBV this will involve workshops to gain better data from the Phase 3 Engineering Consultants and other relevant parties.

Having identified and acquired such cost data it needs to be checked for accuracy and reliability. Particularly with published data, we need to understand what is, and more importantly, isn’t included within each item, and what further allowances or adjustments will be necessary in order to normalise the data to a common denominator, with particular regard to the following:

- Location (with particular regard to local labour and material costs)
- Base date at which the data is priced. (in order that this can be adjusted to a common baseline date)
- Programme (where delivery targets or restraints may influence productivity or other contributory factors)
- Site specific factors (access, restraints on economic working etc)
- Market or other economic conditions

Having reviewed these factors in each case, rates have been adjusted as necessary to a common “base” either manually or by utilising a statistical analysis over a range of alternative rate sources to establish a common ground.

3.3. Process

The Cost Model allows the input of quantities by two methods. Firstly, as an overview at output definition stage, quantities can be determined from historical data, developed into a % of element per route km. Secondly, as the scheme develops, the quantities can be measured by element, as defined in Section 3.3.2. The elemental unit rates can be applied to the quantities derived by either method.

3.3.1. Format

The Cost Model format follows a recognised standardised layout which can be used to manage cost estimates throughout the scheme development and investment cycle, from output definition to project close out. It is based on best practices used within the construction industry and is recognised by major professional bodies. The stages of this cycle are set out below:

- Output definition
- Pre-feasibility
- Option selection
- Single option selection
- Detailed design
- Construction test & commission
- Scheme hand back
- Project close out

3.3.2. Cost Breakdown Structure

For reporting purposes, the resulting costs have been split into three main categories and respective sub-categories:

Contractor's direct costs

- Signalling & Telecoms
- Electrification & Plant
- Track
- Operational Property
- Structures
- General Civils
- Utilities
- Depots

Contractor's indirect costs

- Preliminaries
- Design
- Testing & Commissioning
- Training
- Spares
- Other - Possession Management, Isolations, etc

Client's indirect and other costs

- Client's Project Management
- Compensation Charges (TOC & FOC)

- Planning & TWA Charges
- Land / Property Costs & Compensation

3.3.3. Required Inputs

Whist determination of elemental quantities by percentage of route length will provide a good order of cost estimate up to pre feasibility a more detailed and reliable cost model would depend on the input of measured quantities based on a defined route. The level of quantum will be determined by the level of design details and outputs.

For Phase 3, we suggest the model would require the data outputs for the manual input of the following elements:

- Length of new single and double track (new corridor) (including “normal” signalling, electrical, telecoms)
- Length of upgrading existing single track (existing corridor)
- Length of new single track and upgrading existing track (existing corridor)
- Other railway systems (overall signaling centre/system, overall electrical system, GSMR masts, etc)
- Length of various types of foundations (pile dwelling, concrete pavement tile, etc)
- Earthworks cuttings
- Earthworks embankments
- Length of tunnels and proposed construction methodology
- Number of railway bridges (single/double track) and outline geometry
- Number of passenger end stations (several types including track, platforms, switches/turnouts)
- Number of passenger intermediate stations (several types including track, platforms, switches/turnouts)
- Number of crossings, passing loops and track junctions
- Number of level crossings (road bridges) (small, medium, large)
- Other types of concrete structure/works
- Number of depots & layout
- Number of buildings/area for maintenance facilities
- Rolling stock
- Environmental actions (noise reduction)
- An estimate of the proportion of urban/agricultural/forest land along the route as a % of the route
- Type of traffic (mixed, freight, passenger)

3.4. Sources of Information

The schedule of information resources utilised in the compilation of the cost model are listed below:

- “Concept Evaluation, Cost Estimate and Uncertainty Analysis”, Metier, Oslo, 2007
- “Comparison of High Speed Lines' CAPEX”, BSL, Hamburg, 2009
- “HS2 Cost and Risk Model”, HS2, London, 2009

- “High-Speed Rail Development Programme”, Systra and MVA Consultancy, 2009
- “Feasibility study on Rail, Baltica railways” COWI, 2007
- “Economic Analysis of High Speed Rail in Europe” Fundacion BBVA, Bilbao, 2009
- “High Speed Rail: International Comparisons”, Steer Davies Gleave, London, 2004
- “Prices and Costs in the Rail Sector”, EPFL, Lausanne, 2001

3.5. Base Data

Previous studies noting the limitations of them

- In house historical data
- Client based data
- Published data – country related
- Sense checks of data for accuracy and reliability and coverage
- Rates will be reviewed and adjusted as necessary for: location; market conditions, economic conditions, programme, definitions, etc

3.6. Working Assumptions

In preparing this Cost Model the following assumptions have been made:

- Base date – the date all construction and life cycle prices are based at, (i.e. 1st Quarter 2006)
- Construction programme dates including lead in time for planning & approvals
- Cost sensitive elements which will have the most impact in the decision making; and
- Summary of key assumptions made in developing the unit rates for the model by element are scheduled below

3.6.1. General

- The model is set up to currently show an Order of Magnitude Estimate based upon a notional Scenario D route corridor
- The estimates are based at 1st Quarter 2006 price levels
- Prices are expressed in Norwegian Kroner
- The prices are at a base (point) estimate level. A small allowance has been made for measurement accuracy. There is an allowance for Risk & Contingency based on a 20% uplift plus the value of the deviation from historical data.
- No firm design proposals have been prepared, therefore the scope of works is deemed to be provisional
- The Unit rates are based on rates derived from similar High Speed European railways. They are high level unit rates and have been benchmarked against similar rates provided by Systra, BSL and Metier studies
- The rates reflect the assumption that the works will be carried out by an experienced international railway contractor and the works shall be competitively tendered
- No allowance has been made for operation or maintenance costs within the CAPEX figures. Reference for these should be made within the OPEX Summaries

- An adjustment factor has been added - This is for rate adjustment for factors such as:- Unmeasured Items, Development, Complexity, Location - all of which are NOT included within the Risk Contingency

3.6.2. Permanent-Way

- "Parameters used in deriving the Unit Rates are as follows: Ballast Density 1.6 t/m3; Spoil Density 1.7 t/m3
- Track Bed Width 7.5 m; Sleeper Spacing 700 mm
- Ballast Depth 600 mm; Sand Blanket 200 mm
- Ballast width 3.8 m; Rail UIC60, R65 CWR"
- Rates priced at cost/linear km and assume a 7.5 metre wide track bed
- The rates are based on a slab-track solution similar to the Rheda 2000 system. Adjustment has been made to match the project specifications
- The rates were built from first principles and include plain line, site clearance, shallow depth excavation and formation preparation, fencing, signage, drainage, allowance for UTXs. We have assumed that 30% of the spoil resulting from the formation works is contaminated
- No passing loops required for Scenario A - New High Speed Line - this needs to be assessed at a later stage
- Switches and crossings have been measured and priced as extra over the plain line track and allow for: additional excavation; formation; ballast; configuration of the fitting, points heating, clamplocks and backdrives, testing and commissioning
- All S&C units are full depth, built on site. The S&C units were divided into two categories, low, and high speed. Unit rates built from first principles
- Allowances for land reclamation or flood relief work are measured as an extra over the base trackwork rate

3.6.3. Structures

- Rates based on bored tunnel, cut & cover and drill & blast methodologies, measured extra over trackwork
- Pricing assumes the acquisition of 2nr Tunnel Boring Machines" "Rates are based on recovered data and information from approximately 50 separate structures completed as part of actual projects. The rates include excavation, reinforcement, formwork, concrete, bearings, expansion joints, deck waterproofing, deck finishes, P1 parapet and lighting. In addition a cost model was developed to determine cost as a function of the variation in height of the viaducts
- Viaduct construction assumed to be simply supported span sections in steel and/or concrete."
- The rates been derived from cost /m2 deck area. Bridges have been defined by road size. Rail over rail bridges /crossings have been specifically identified. Where bridges, spans exceed economical length over 80 metres, viaducts have been assumed. Bridge construction assumed to be simply supported span sections in steel and/or concrete. Bridges have been categorised according to location and circumstance - road, river, etc and priced in span ranges accordingly

3.6.4. Earthworks

- Embankments & Cuttings have been measured and priced as extra over the trackwork
- Cuttings and Embankments cross-sections assumed a 7.6 m track bed width and slopes graded at 45° (assumed below natural angle of repose). It was assumed that 70% of the

earthworks grading is adequate. For the remainder 30% an allowance was made for earth stabilisation methods, in particular, soil nailing and rock netting

- A cost model was developed to express cost as a function of depth/height of the cutting/embankment and the volumes of excavation/fill have been split into 5m depth/height intervals and costs calculated from the respective average rate"
- An allowance was made for utility diversions

3.6.5. S&T

- The signalling system is ERTMS level 2
- The telecoms system is GSM-R

3.6.6. E&P

- 25kV 50HZ overhead line equipment
- The system priced is an Autotransformer system
- There will be 30 km between every feeder station
- An allowance was made for SCADA remote monitoring

3.6.7. Buildings

- Allowance was made for Electrical Control Centre, Signalling Control Centre, Administration Buildings, Depots, etc
- Unit rates have been build up on a cost/m2 GFA basis with additions for Plant, Services. Etc

3.6.8. Quantities

- The route lengths were obtained using the road routes in between the terminus stations. The take-off has got a very low degree of accuracy
- For the purpose of this exercise typical topography for Northern/Central Europe was incorporated into the model in order to determine the quantities of bridges, viaducts, tunnels & earthworks
- For the purpose of this exercise the full station construction cost was included in the cost model instead of a major refurbishment/upgrade cost. The difference in overall cost, taking into account the magnitude of the final overall cost is negligible

3.6.9. Rolling Stock

- Rolling stock requirements based on rough estimates at this stage
- The selected rolling stock will be "off the shelf" TGVs for passenger use only and standard freight locomotive and wagons. Adjustments for cost can be made to the model upon specification of type in Phase 3

3.6.10. Indirect Costs

- Prices are inclusive of Contractor's overheads & profit
- Preliminaries & Professional Design & Management Fees have been shown separately as a percentage of the base figures

3.7. Exclusions

Additionally in arriving at the unit rates and preparing the Cost Model the following have specifically been excluded at this stage:

- Value Added Tax & other taxes

- Escalation during the lead in and construction periods (i.e. all costs are therefore based at 1stQtr 2006 price levels)
- Capital Allowance costs, finance charges etc (added in the financial model)
- Track access and operational charges (included in the life cycle cost model)
- Existing track upgrade cost
- Development Study costs (i.e. project development studies from 2010 onwards)
- Legal & Parliamentary/ Governmental Fees
- Estate, Local Planning Fees
- Public Consultation costs
- Third party compensation
- Professional & other Adviser Fees to Feasibility stage
- Environmental, Ecological & Geotechnical studies
- Project Contingencies (added in the financial model)

3.8. The Cost Model

A 'dummy' run through of the cost model based on a notional route alignment and the feed through into the financial and economic models has been undertaken. In Phase 2 and going forward into Phase 3 the Cost Model comprised in Excel contains the following data sheets:

- Summary & Inputs – This section is to be populated by the user, at Phase 3, which should select a number of basic parameters to define the rail route to be estimated. These parameters include route option length, number of tracks, type of tunnelling, type of signalling, currency (default is Norwegian Kroner) and base date (default is 1Q2006). By completing the Inputs a Cost Summary is generated in total and by Route Option
- Report – The report section offers a number of reports that include the estimate broken down following different criteria. The model reports on both the statistical and estimating model and offers comparisons with a number of studies and actual costs of similar projects
- Unit Rates – The unit rates selected as described in Section 4.2.4 are nett rates. In this section the rates are converted to gross rates and the individual elements converted to unit rate per Km or Sums
- QTY – The topography is defined in this section. The data can be manually input to generate costs for different topography profiles. By default the model selects historical data for the typical Northern Europe topography (extracted from several similar schemes in this area). The selection between the two options is made by switching the cells "Earthworks, Tunnels & Viaducts Quantities" and the "Crossings" lines, in the Input section, from "statistical" to "input"
- Per Option 1,2,3 & 4 – The rates and quantities are linked to these tabs which then compile the direct costs for the respective route (section) option. These option totals are determined by the Inputs and then carried forward to the Summary. All direct costs are expressed in either unit rate per km or sum. The indirect costs are calculated based on percentages
- During Phase 3, the cost model will be used in an iterative process in conjunction with the Alignment engineers to develop the most cost efficient route alignment for client assessment

4. Life Cycle Cost Modelling

4.1. Introduction

The purpose of the life cycle modelling is to provide JBV with order of magnitude cost estimates for maintenance (which covers asset renewals) and operation in addition to the capital costs to ensure that the life cycle costs (LCCs) over the long-term are included as part of the overall economic assessment at this the feasibility stage.

The aim is to provide a robust and workable high-level life cycle costing appraisal model that can test different high speed rail options. The LCC model has to conform to the capital cost data structure and provide inputs into the economic and financial models. The life cycle cost model has been tested at this stage using a notional route alignment to demonstrate functionality, although the numbers are 'dummy' at this stage and should not be considered conclusive.

4.2. Methodology

The life cycle costing methodology will conform to the BS ISO 15686-5:2008 Building & constructed assets - Service life planning- Part 5 and to the 'Standardized Method of Life Cycle Costing for Construction Procurement' which is a supplement to BS ISO 15686-5:2008.

The main life cycle cost headings to be included in the assessment are:

- Construction – initial capital construction work costs
- Maintenance – major replacement; subsequent refurbishment; redecorations; scheduled planned preventative; reliability centred and reactive maintenance costs
- Operation – utilities; administration; staffing & cleaning costs, fuel/power

NB other costs such as finance and strategic non-construction cost that relate to Whole Life Costs are covered in the financial model. End of Life Costs are not included in the LCC model. Where appropriate, a residual value for assets which have life remaining at the end of the assessment period will be calculated in the financial model using asset lives determined as part of the cost estimation process.

During Phase 2, the Baumgartner report was reviewed and the methodology / assumptions have been adopted for the preparation of the initial life cycle costs. The life cycle maintenance costs are based on a percentage of capital construction costs. The annual maintenance costs are based on a long term average at the price level on the date of commissioning of the equipment and correspond with a yearly percentage of the investment. The life cycle operating costs are based on UK High Speed Rail data.

For Phase 3, the Baumgartner percentages will be developed to reflect predictive services lives for each of the costed assets. These lives will be used to determine residual values.

4.3. Process

The process for developing the life cycle modelling includes the establishment of the scope of the life cycle costs to be included in the LCC model has been under the following headings – Construction, Maintenance and Operation. The Work Breakdown Structure (WBS) for the capital costs has been followed:

- Lifecycle maintenance costs
    - Signalling & Telecoms
    - Electrification & Plant
    - Track
    - Operational Property

    - Structures
    - General Civils
    - Utilities
    - Depots
    - Rolling Stock
- Life cycle operating costs
    - Station Staffing
    - Train staffing & management
    - Energy Consumption

During the preparation of the cost model, available life cycle, maintenance and operating data for high-speed rail has been reviewed. Different LCC methodologies have been applied to each of the WBS items depending on whether they are influenced by changes in demand, passenger numbers, types of passenger and freight rolling stock, frequency of use, staffing and other factors that can influence the component lives or a combination thereof. All information and data assumptions have been recorded.

4.4. Sources of Information

Schedule of Information Sources includes:

- High Speed Rail London to the West Midlands and Beyond HS2 Cost and Risk Model - December 2009
- ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE PRICES AND COSTS IN THE RAILWAY SECTOR J.P. Baumgartner Professor - January 2001
- Jernbaneverket METHOD HANDBOOK JD 205 Economic analysis for Norwegian Railroad - June 2006

4.5. Working Assumptions for the Model Test

For the ‘dummy’ run through of model, the LCC model has been tested using a notional route alignment Scenario D from Oslo to Bergen and Stavanger via Bo. The outputs are not conclusive as the test has not been based on sufficiently detailed route alignments and design and the test is to demonstrate model functionality and format of outputs only. Risk and sensitivity analysis has been applied to the LCC model. Complete LCC profile and report has been issued in Excel.

- **General assumptions for Scenario D from Oslo to Bergen and Stavanger via Bo**
    - Period of life cycle cost analysis 40 years post commencement of operation. A 25 year life cycle cost analysis can also be accommodated.
- **Life cycle maintenance costs**
    - Generally based on J.P. Baumgartner percentages of capital construction cost
    - Annual maintenance costs based on long-term average, at the price level on the date of the commissioning of the equipment (yearly percentage of the investment)
    - The methodology allows for management and administration during the operation period
    - Rolling stock based on:
        - It has been assumed that the rolling stock will be "off the shelf" TGVs for passenger use only and standard freight locomotive and wagons. The model will accommodate alternative types and can be adjusted once specified in Phase 3.

  - 27 trains (24 in operation, 2 maintenance and 1 'hot spare')
  - 3 round trips per train, 364 days per year
  - 532 km each-way from Oslo to Bergen
  - 546 km each-way from Oslo to Stavanger
  - Journey time - 2 hrs 30 mins with a 30 min lay over at either end

- **Life cycle operating costs**
  - Generally based on High Speed rail cost benchmarks
  - Assumed 1 main terminus station, 2 country terminus station and 3 intermediate stations
  - Assumed 7hr working day
  - Assumed 364 operational working days per annum
  - Assumed 34 train journeys per day
  - Assumed 2 drivers, 1 conductor and 2 catering staff per train
  - Assumes 2 crew management staff
  - The following hourly rates have been assumed:
    - Driver NOK 375
    - Conductor NOK 305
    - Catering NOK 200
    - Crew Management NOK 500
  - Infrastructure energy consumption £5,000/km/yr converted to NOK 42,640/km/yr
  - Traction rolling stock energy consumption (per train set) is based on 28 kWhr/km
  - Cost of electricity assumed at £0.10/kWhr converted to NOK 0.95/kWhr

Outputs from the test are shown in Appendix B.

5. Risk and Estimating Uncertainty

5.1. Introduction

The primary objective in managing project risk is to identify, understand and then remove completely all risks, if possible to do so. Where this is not possible they should be reduced and stakeholders should be informed of the level of residual risk.

Several studies have indicated that project cost estimates tend to underestimate costs and delivery times and overestimate benefits and revenue streams. This is usually due to biases unwittingly inherent in any projects early development, and risks and uncertainties that materialise in the course of the project. This is managed in the UK by the introduction of ‘Optimism Bias’ as part of economic assessments. This adjustment is added to capital costs (that already include a quantified risk allowance for known and measureable risks) to take account of unforeseeable cost increases and the tendency for cost over runs in similar significant infrastructure projects. As part of the Subject 4 (Economic Analysis) work for this contract, a study has been undertaken to review actual compared to forecast costs and an appropriate uplift for costs has been recommended. This will be set at 66% at this pre-feasibility stage of development i.e. in Phases 2 and 3 of this work.

This chapter deals with quantified cost risk assessment process which is carried out as part of cost estimation, to which the additional uplift allowance is added as part of the economic analysis only.

Three main stages in the life of a transport project have been identified which give an indication of the quality of risk assessment and cost estimate typical of schemes at the different stages of scheme development. The three stages are:

- Stage 1 – Pre Feasibility – minimal ability to undertake detailed risk assessment due to limited information
- Stage 2 – Option Selection – qualitative/ pseudo quantified risk assessment (QRA) can be undertaken
- Stage 3 – Design development – quantified risk assessment is possible

5.2. Estimating Uncertainty - Methodology

From the rate compilation and comparison exercises undertaken so far, it is clear that there exists the potential for a considerable range of costs dependant on the design proposals which are ultimately developed. During the preparation of this estimate a considered view has been taken as to the most suitable cost within this range, weighted in line with the anticipated scheme specification and characteristics identified from the development work undertaken to date.

Because of this and the nature of the supporting information and level of development of the Capital Cost estimates presented to date, the estimates should currently be regarded as having an average tolerance of no better than +30 to -10%, although individual elements of the estimate may exceed this.

As better data becomes available, a more sensitive estimating tolerance exercise will be undertaken. The method that will be employer will be to review each elemental cost plan entry and review both the specific rate and quantity for potential variance either +ve or –ve. This method will be adopted.

5.3. Discrete Risk

Most scheme promoters expect a project to provide evidence that they have adopted a systematic approach to risk management. This is in essence a structured approach to identifying, assessing, and responding to risks that occur during a project. In order to adjust the base cost for the risks associated with any project, a Quantified Risk Assessment (QRA) is normally conducted.

A QRA allows a probability distribution around the costs of the scheme to be derived and enables the expected risk-adjusted cost estimate to be obtained. This expected outcome, also known as the 'mean' or 'unbiased' outcome is the weighted average of all potential outcomes and associated probabilities.

Examples of the detailed risks to be considered during the next phase of the project are anticipated to include but not limited to the following key issues:

- Planning Consent / Concession Risk (i.e. issues with High Speed Corridor Reservation)
- Utilility diversions/ protection works approvals
- Highway approvals for permanent / temporary modification
- Environmental issues
- Sites specific issues such as:
    - Limits of deviation
    - Land required for stations, depots, car parks, etc
    - Temporary construction activities
- Technical Issues:
    - Incomplete or inaccurate information
    - Unworkable scope elements
    - Poor detailed design
    - Technology risk
- Power Availability
- Construction Risk
    - Interface with other key contracts
    - Changes in design
    - Approvals of temporary works
    - Enabling works
    - Site accessibility
    - Permanent works long lead items include rolling stock, travelators, elevators and escalators and special depot equipment. Temporary works long lead items include the tunnel boring machines (TBM’s), viaduct launching gantries (or similar), and any other special plant
- Operating Risk
- Revenue / Market Risk
- Regulatory / Political Risk
- Legal Risk

5.4. Risk Identification

Risk identification will be initiated and continued throughout the project lifecycle as new risks (unallocated risks) are identified or existing ones updated or retired. Risk identification should focus on specific events and describe both the causes and the consequences of particular risks on the project.

5.4.1. Risks, Opportunities & Issues

It is important that the items contained within the register are risks and not issues. In the context of the Norwegian High Speed Rail study risk management:

- A RISK is an uncertain event or set of circumstances that, if it occurs, will have either a positive or negative effect on the project's objectives and is measured through a combination of impact and likelihood
- A THREAT is 'an uncertain event or set of circumstances that should it occur, will have a NEGATIVE effect on the project's objectives'
- An OPPORTUNITY is 'an uncertain event or set of circumstances that should it occur, will have a POSITIVE effect on the project's objectives'
- An ISSUE is a problem that currently affects the project that is being dealt with through ongoing project management activities

5.5. Risk Evaluation

All identified risks should be evaluated in terms of likelihood of occurrence and potential impacts on the project in order to prioritise their management and determine the current level of risk exposure. Risks are qualified via a combination of probability and impact. Standard probability and impact "bandings" will be defined and will be used to qualify all risks. It is important that the impact bandings are in proportion to the size of project being undertaken. The exact values of impact scale will be determined during the initial stages of Phase 3.

If a good history of the risk is available or there is better knowledge, whereby the impact can be more accurately defined, a quantitative assessment can be undertaken.

For each risk item, a risk severity score is derived from the combination of its probability score and its impact scores. Each risk will then be graded into a Red, Amber or Green category, where Red is a more significant risk item.

5.6. Risk Treatment

Once risks have been identified and their relative significance established, suitable management responses should be developed to manage them. The aim of risk treatment is to reduce overall risk exposure to the Employer and Alliance while enhancing and realising opportunities. All responses should be SMART (Specific, Measurable, Achievable, Realistic and Time bound), have an appropriate risk owner responsible for implementation and a deadline by which the action should be completed.

Having sorted the risks into those with the greatest potential to impact on the project's objectives, management actions can be developed. Depending on the time available, normally the red risks will have actions developed as a priority.

6. Conclusions

This report details the work that has been undertaken to set up cost estimation models that will be used to estimate costs of alternative scenarios for high speed rail improvements in Norway. A "Cost Model" has been established and associated methodologies for CAPEX, Life Cycle, Risk and Uncertainty have been defined. These models and methodologies will be employed in Phase 3 of the study to estimate costs using outputs from the detailed route alignment studies and more detailed scenario specification. The cost estimations will be used in the financial and economic assessment in Phase 3, which will show the performance of alternative scenarios on each route under consideration.

The Phase 2 deliverables may be subject to some minor upgrades and alterations during Phase 3 due to:

- Identification of additional scope items that become evident upon the release of route specific output specifications
- Unanticipated emerging requirements from either JBV or other members of the Phase 3 project team
- Emerging additional client requirement

The model has been set up in such a way that they can cope with the identification of variations in the assumed rates and quantities. The detailed application of the Quantified Risk Assessment (QRA) process for CAPEX and Life Cycle costs will be undertaken during the next phase.

6.1. Capital Cost Modelling (CAPEX)

In Phase 2, the cost model has been prepared, as described above to provide a robust tool to enable the informed route assessment during Phase 3. The cost model has been tested using a notional Scenario D route alignment from Oslo to Bergen and Stavanger via Bo to demonstrate model functionality and the format of the outputs. The Phase 2 Model picks up the base costs for any particular alignment together with cost variations within the key elements such as cuttings, embankments, tunnels and the like. The Model also has the flexibility to be applied to single or double track scenarios. Risk and sensitivity analysis has also been applied to the model outputs. The result of this activity can be found in Appendix A to this report.

Several previous studies that have been considered as part this activity including the previous JBV studies, HS2 from the UK and J.P. Baumgartner percentages of capital construction cost. These have also been used as the basis for the establishment of the Life Cycle Cost (OPEX) model. All of the available data has been reviewed and an appropriate set of Norwegian High Speed Rail unit rates have been developed. These project specific unit rates will be used as the basis for the Phase 3 estimating. These rates will be reviewed with JBV and developed and harmonised over the course of the next phase.

To populate and develop the model, a schedule of input data required from each of the Phase 3 engineering and design consultants has been prepared. This specification defines what data is required from the route specification process to feed into the cost model. This schedule should be issued to the Phase 3 engineering and design consultant for comment. Once this schedule has been agreed, this will form the basis of the interface between the cost model and the emerging design.

The client brief noted that there were a number of scenarios that need to be considered such as minimal upgrades to the existing network, mixture of upgrade of existing and cut-off, new high speed route plus the possible requirement for freight. The model at Phase 2 has been developed in such a way that it has the flexibility to cope with the majority of these scenarios. During the next phase, some minor modifications may be required to meet changes to the assumptions contained in the model as a result of any emerging route options that have not at this stage been considered.

6.2. Life Cycle Cost Modelling (Life Cycle)

In Phase 2, the life cycle cost model has been established and has also been tested using the notional Scenario D route alignment from Oslo to Bergen and Stavanger via Bo to demonstrate model functionality and the format of the outputs. During Phase 2 the Life Cycle model was developed in line with the Capex cost model and aligned with the established WBS. The model is proven by reference to published and recognised guidelines and the review of similar costs for High Speed Rail schemes. Assumptions generally are based around the Baumgartner report. Risk and sensitivity analysis has also been applied to the life cycle costs. The results of this work can be found as an appendix to this report.

Further work will be carried out to the life cycle cost model in Phase 3 to ensure that asset lives are determined for the residual value requirements. In addition we will incorporate all available relevant data has been captured i.e. as part of Phase 3 sources of specific JBV operational and maintenance data will be sought.

Appendix A – Capital Cost Model Example

It should be noted that the outputs here and Appendix B are for a 'dummy run' of the model and are not accurate forecasts for a fully defined option. They are presented here to show the format of the outputs that will be available in Phase 3 of the project.

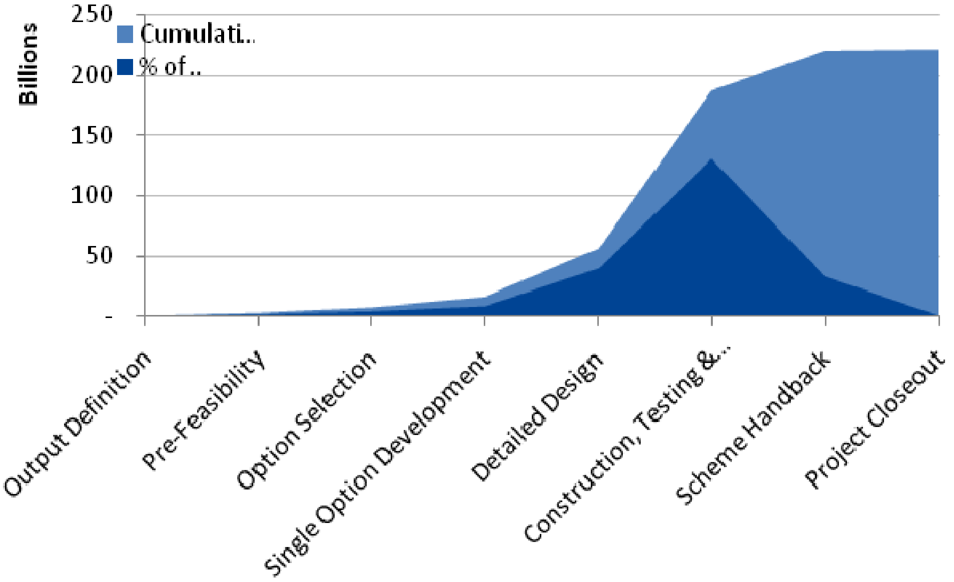
A.1. Summary Report

Estimate Summary Report

Estimate No	**001**	**Revision**	**11.0**
Estimate Date	**11-Jan-11**	**Base date**	**2006**
Project Title / Location	**High Speed Rail - Cost Model v11.0**		

Estimate Breakdown	Value	%
Contractor's direct costs		
Signalling & Telecoms	5,162,431,160	4.7%
Electrification & Plant	6,271,171,576	5.7%
Track	14,511,321,123	13.1%
Operational Property	3,619,942,856	3.3%
Structures	46,753,657,254	42.2%
General Civils	28,277,768,836	25.5%
Utilities	3,303,262,523	3.0%
Depots	2,920,821,054	2.6%
Sub-Total A	**110,820,376,382**	
Contractor's indirect costs		
Preliminaries	22,354,275,740	20.2%
Design	8,653,066,356	7.8%
Testing & Commissioning	1,414,961,448	1.3%
Training		0.0%
Spares		0.0%
Other - Possession Management, Isolations, etc	5,461,442,564	4.9%
Sub - Total B	37,883,746,108	34.2%
Total Construction Cost E (A+B)	**148,704,122,491**	
Client's indirect and other costs		
Client's Project Management	5,541,018,819	3.7%
Compensation charges (TOC & FOC)		0.0%
Planning & TWA Charges	7,699,388,392	5.2%
Land / Property Costs & compensation	1,531,062,180	1.0%
Sub - Total C	14,771,469,390	
	163,475,591,881	
Uplift for Risk and Contingency		
Contingency - Model Accuracy @ 20%	32,695,118,376	
Standard Error 16.18%	26,447,195,066	
Project Anticipated Final Cost (AFC)	**222,617,905,323**	
Rolling Stock	6,792,507,939	
Allowance for fee funds, industry risk fund and insurance top-up		
Cost to Customer	**229,410,413,262**	

A.2. Spend Profile



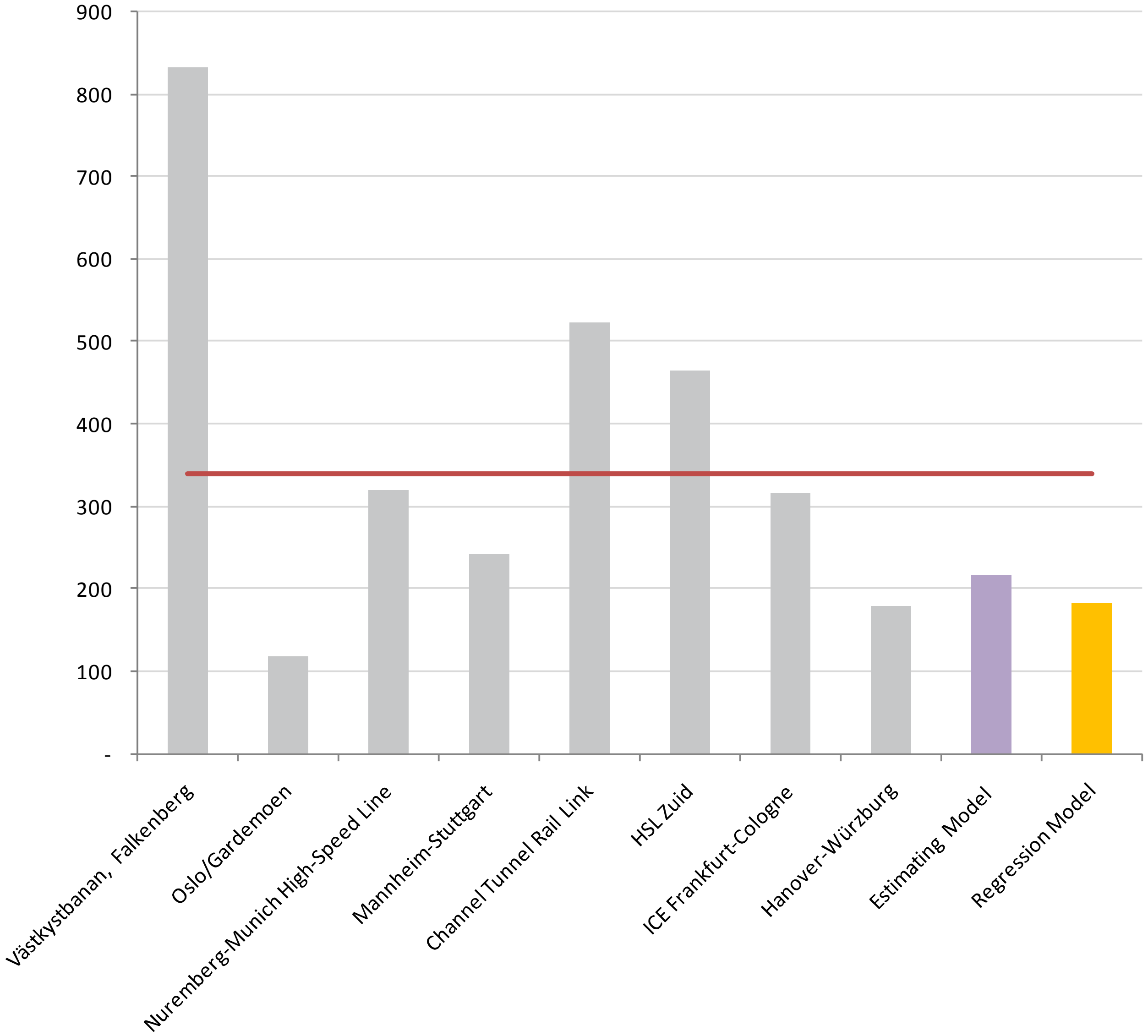
A.3. Unit Rates

Permanent Way

Track		Unit	Quantity	Rate	Total
	Formation	single track km	2	1,247,212	2,494,424
	Drainage - twin track	single track km	2	1,918,788	3,837,575
	Rail, Sleepers & Ballast	single track km	2	3,837,575	7,675,150
	Delivery of Materials & Tamping	single track km	2	959,394	1,918,788
	Lineside fencing -pallisade fencing	single track km	0	1,266,400	-
	Track Renewal	single track km	2	7,675,150	15,350,300
					15,925,937

S&C		Unit	Quantity	Rate	Total
	Crossovers	number	30%	5,660,423	1,698,127
	Crossovers (Emergency / Low speed)	number	10%	4,317,272	431,727
	Turnouts	number	30%	3,252,345	975,703
	Turnouts (Low speed)	number	10%	2,398,484	239,848
	Twin track tie in of new to existing route - normal operations	Number	0%	13,431,513	-
	Twin track tie in of new to existing route - emergency use	Number	0%	7,195,453	-
					3,345,406

A.4. Cost Benchmarking



A.5. Parameters

Parameters

Nr of Tracks	2		Nr
Signalling System	ERTMS 2		Type
Tunnelling Method	Cut & Cover		Type
Earthworks, Tunnels & Viaducts Quantities	Statistical		Data
Crossings	Statistical		Data
Topography Factor	0		[0:5]
Track Bed Width	12		m
Nr of Intermediate Stations	3		Nr
Nr of Terminus Stations	2		Nr
Length - Route Option 1 - New High Speed Line	753		Km
Length - Route Option 2 - High Speed Upgrade	0		Km
Length - Route Option 3 - Double Tracking + High Speed Upgrade	0		Km
Length - Route Option 4 - Do Minimum	0		Km
Total Route Length	753		Km
Currency Factor (excludes PPPs) - Jan 2010	8.15		NOK
Base Year	2006		Year
Standard Error	16.2%	41.07	0.02%

Appendix B – Life Cycle Cost Model Example

B.1. Life Cycle Spend Profile Extract

High Speed Rail - Cost Model v12.0

Cost Profile- GRIP		Year				
		0	7	8	9	10
Construction	**Years**					
Planning & Associated Costs	1	121,944,092				
Output Definition	0.2					
Pre-Feasibility	0.3					
Option Selection	0.5					
Single Option Development	1					
Detailed Design	0.5					
Construction, Testing & Commission	2.2					
Scheme Handback	1					
Project Closeout	0.1					
Rolling Stock Assume 1 year lead time						
Total Construction	5.8		0	0	0	0
Life Cycle Maintenance Cost						
Annual Life Cycle Maintenance Cost			140,909,487	140,909,487	140,909,487	140,909,487
Life Cycle Operating Cost						
Annual Life Cycle Operating Cost			117,690,242	117,690,242	117,690,242	117,690,242
Total life cycle		**121,944,092**	**258,599,729**	**258,599,729**	**258,599,729**	**258,599,729**

B.2. Life Cycle Maintenance Annualised rates for Track

LIFE CYCLE MAINTENANCE
Indicative average annual lifecycle costs, from Baumgartner report. Based on % of initial investments, unless otherwise indicated

Permanent Way	Ref.	Range From	Range To	Comments	Basis	Av annual rate
Track						
Formation	3.1.3.3	0.00%	1.00%		0.50%	12,472
Drainage - twin track	3.1.3.3	1.00%	3.00%		2.00%	76,752
Rail, Sleepers & Ballast	3.1.4.3	€ 40,000	€ 60,000	Euros per km of track. 2 way therefore have doubled so per railway		€ 100,000
Delivery of Materials & Tamping				No lifecycle cost		-
Lineside fencing -pallisade fencing						-
Track Renewal						
					Subtotal	**189,224**
S&C						
Crossovers	3.2.3	5.00%	15.00%		10.00%	169,813
Crossovers (Emergency / Low speed)	3.2.3	5.00%	15.00%		10.00%	43,173
Turnouts	3.2.3	5.00%	15.00%		10.00%	97,570
Turnouts (Low speed)	3.2.3	5.00%	15.00%		10.00%	23,985
Twin track tie in of new to existing route - normal operations	3.2.3	5.00%	15.00%		10.00%	-
Twin track tie in of new to existing route - emergency use						-
					Subtotal	**334,541**

B.3. Annual Life Cycle Maintenance Costs (Extract)

	TOTAL ANNUAL LIFE CYCLE MAINTENANCE COSTS		
Signalling & Telecoms	**Rate**	**Qty**	**Total**
Signalling	227,299	753	171,156,125
Telecoms	139,084	753	104,729,938
Signalling Control Center	1,060,024	1	1,060,024
Interlocking	722,743	60	43,538,057
Electrification & Plant			
OLE & E&P	212,937	753	160,341,398
Electrical Control	826,181	1	826,181
Permanent Way			
Track	189,224	753	142,485,387
S&C	334,541	753	251,909,079
Civils			
Earthworks	93,952	753	70,746,048
Utility diversions	0	753	0
Acoustic Barriers	124,721	753	93,915,057
Viaducts	40,697	753	30,645,030
Tunnels	39,891	753	30,038,145
Crossings	2,711	753	2,041,250

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