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GLOSSARY

| | |
|-----|----------------------------|
| ATP | Automatic Train Protection |
| CBS | Cost Breakdown Structure |

| | |
|--------|--------------------------------------------------------------------------------------------------------------------|
| CP | Central Position |
| CUE | Central Unit Equipment |
| HOAI | Honorarordnung für Architekten und Ingenieure (Office of Scale Fees for Services by Architects and Engineers) |
| OC | Object Controller |
| LEU | Lineside Electronic Units |
| LX | Level Crossing |
| NR-WIC | NetworkRail Work Item Catalogue |
| PM | Projekt Management |
| RACI | Responsible, Accountable, Consult, Inform |
| RBC | Radio Block Center |
| SEU | Signal Equivalent |
| SFA | Service Framework Agreement |
| SLA | Service Level Agreement |
| TOC | Train Operating Compensation |
| TWA | Transport and Work Acts |
| WBS | Work Breakdown Structure |

Section 1 – EXECUTIVE SUMMARY

The objective of WP B 2.2 is to identify market specific cost drivers for signalling systems. This has to be done by analysing the cost calculation approaches for each INESS participating country. Once the cost drivers are determined, they will be analysed by studying signalling systems for each market segment. Deliverable D.B.2.2 will give a report on market specific cost drivers and how they are determined. The cost calculation approaches of each WP partner were analysed in terms of:

- Considered items
- Calculation methodology

First a cost calculation matrix (section 4.1) was prepared to get an overview about the relevant items. The matrix is split into part 1 (“technical items”, “other items”) and part 2 (“extraordinary efforts”, “others”). The cost calculation matrix was filled out by every WP partner. Every WP partner was free to extend the matrix to make sure that all relevant aspects were covered. After the cost calculation matrixes have been filled out, they were arranged all together to make similarities and local differences visible. Second step was to analyse the cost calculation approaches of each WP partner to see the different cost calculation methodologies. A detailed description of each cost calculation approach is available in section 4.2.

The comparison of the cost calculation matrixes showed that nearly the same “technical items” are considered by each WP partner with three exceptions (Balise (LEU), RBC interface and RBC). These three items seem to have particular characteristics causing a special treatment for cost calculation. Comparing “other items” within part 2 of the cost calculation matrix discloses that nearly no partner included items from these categories. Only labour cost is considered by all. The most complex calculation is done by NetworkRail as they are the only partner taking a lot of “other items” into account. Finally the relevant items have been identified and it has become apparent that there are only a few “other items” regarded for calculation. Focusing the cost calculation approaches two methods are used between the INESS partners. Either surcharge calculations or probabilistic models are applied to calculate the total project cost. Both types enable to include project risks (project duration, geographical risk, etc.). A possibility is to calculate scenarios for worst, average and best cases and evaluate them with an occurrence probability rate to estimate the project cost like Banverket and ProRail do.

Section 2 – INTRODUCTION

The goal of WP B 2.2 is the identification of market specific cost drivers and how they are determined. Cost calculation approaches for signalling systems contain predictable items with a fixed value and unpredictable items. Unpredictable items, such as risks are mostly considered by surcharges. As the value of cost drivers is mostly variable it is necessary to identify those and get an understanding how they are influenced. This understanding is necessary to provide reasonable cost estimation in order to take strategic decisions on the project. Furthermore it is needed to show cost reduction potential in order to be competitive on the market. The cost drivers may differ by country, as the evolution of the railway business was mainly affected by national legislation. Therefore it is purposeful to make a research on regional markets by analysing cost calculation approaches of INESS partners.

Section 3 – OBJECTIVES & BACKGROUNDS

3.1 Relevant items for cost calculation

The following section will describe why it is necessary to identify the relevant items for cost calculation and how they are figured out.

It is necessary to define relevant items for cost calculation in order to have common understanding of cost drivers and their influence on the price of a signalling system to manage business in a reasonable way.

Cost drivers need to be controlled carefully as they have a huge impact on the overall costs of a capital investment or project. They may be influenced by project duration, geographical risk, exchange rates, raw material prices, etc. Therefore it is mandatory to get an understanding how this risk is covered. This can be achieved by analysing the cost calculation approaches of each partner

1. focusing on technical aspects
2. focusing on methodological aspects

for finding out similarities, differences and respectively specific approaches.

One of the main goals of the work package is to show cost reduction potential and country specific approaches from which conclusions concerning country specific cost drivers can be drawn. In general cost reduction potential can be located by subtracting actual or budgeted cost from calculated cost. Even though it is an easy mathematical calculation, the result mainly depends on the understanding of the cost structure and the used input. To make an assumption of cost drivers it is required to observe cost calculation approaches for having a generally valid base to predict a reasonable forecast of the cost reduction potential in WP B 3.2 “Quantification of cost reduction potential” later on.

The cost calculation matrix was designed for achieving a comparable overview about all items contained in the cost calculation process of INESS railway partners (see Figure 1). Especially those items contained in the cost calculation can have the potential to boost project costs. In preparation for a workstream meeting every railway partner received a blank template of the cost calculation matrix. Each INESS partner was invited to fill in all relevant items considered for his individual cost calculation. The matrix is structured in two parts.

The first part of the matrix contains suggestions for “technical items” and “other items” which could be regarded for cost calculation. The technical items suggested were already part of the interlocking product structure as part of the INESS life cycle cost collection template. Possible entries for the classification of every item were: “Item is not included”, “Item is partially included” or “Item is included”. Technical items represent the product structure of an interlocking. Exemplary technical items are the traffic control system, the data preparation system or the interlocking kernel. Examples for other items are labour-, maintenance costs or costs for test trains on the signalling system. Also the list of other items in the cost calculation matrix was free to be extended by the railway partners, so that every partner had the chance to add his specific items to the list (see Figure 2).

The second part of the blank cost calculation matrix contains “extraordinary efforts”, “market place characteristics” and “other items”. Examples for extraordinary efforts can be cross border connections or environmental aspects, whereas market place characteristics can be specific standards or contractual issues like risk sharing. Part two of the cost calculation matrix could also be extended by additional points (see Figure 3).

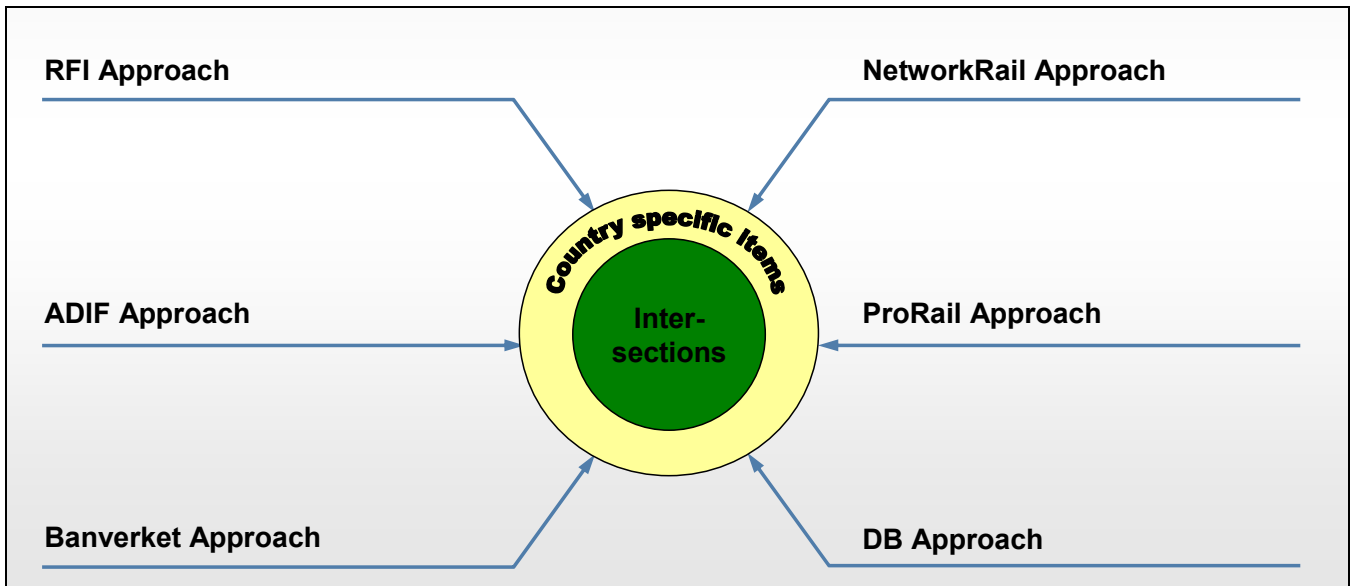


Figure 1: Objective of cost calculation matrix

3.2 Presentation of cost calculation approaches

First objective of comparing the cost calculation approaches is to indicate specific methods of each railway partner to identify cost drivers. Second objective is to understand how risks like project duration, geographical risk, fluctuating exchange rates, etc. are considered. It gives an indication what kind of data is needed and how complex the calculations are. Understanding the calculation methods helps understanding country specific ways to quantify cost drivers in advance of a project.

Section 4 – RESULTS

The first part of this chapter explains the results delivered by the cost calculation matrixes . The second part includes descriptions of the cost calculation approaches of six INESS railway partners.

4.1 Relevant Items for cost calculation

After six railway partners have filled in the matrix, several similarities between regarded items were transparent. An overview about all entries can be seen in Figure 2.

Within the technical items part of the matrix most characteristics have been shared. Nearly half of the technical items (cf. product structure of INESS data collection template) listed in the matrix part 1 are regarded for calculation by all six railway partners with contribution to this task. Juridical recorder, interlocking kernel, power supply incl. UPS, diagnostic system, object controllers for signal, track segments and points, axle counters as well as the civil works and cabling are part of cost calculation for all six railways. Another four items are considered by five of the six participating railways. These are the object controller for Balise, control module, data preparation system and signal. In contrast the Balise (LEU), RBC and RBC (interface) are only contained in the cost calculation of one or two partners.

Among other items the most commonalities can be seen within labour and indirect costs. Labour costs are part of the calculation for all participating railway partners. Indirect costs are – at least partially - included within the calculation of four partners. A big share of the other items is only regarded by one INESS partner.

| | | ADIF | Banverket | DB | Network Rail | ProRail | RFI |
|------------------|--------------------------------------|-------|-----------|--------|--------------|---------|--------|
| Technical | | | | | | | |
| | 1 Traffic Control System | Green | Green | Green | Green | Red | Red |
| | 2 Data Preparation System | Green | Red | Green | Yellow | Green | Green |
| | 3 Diagnostic System | Green | Green | Yellow | Green | Green | Green |
| | 4 Juridical Recorder | Green | Green | Green | Green | Green | Green |
| | 5 Control Module | Green | Green | Green | Green | Green | Green |
| | 6 Interlocking Kernel | Green | Green | Green | Green | Green | Green |
| | 7 Power Supply incl. UPS | Green | Green | Green | Green | Green | Green |
| | 8 OC-LX | Green | Green | Green | Green | Red | Green |
| | 9 OC (Balise) | Green | Green | Red | Yellow | Green | Green |
| | 10 OC (Point) | Green | Green | Green | Green | Green | Green |
| | 11 OC (Track Segment) | Green | Green | Green | Green | Green | Green |
| | 12 OC (Signal) | Green | Green | Green | Green | Green | Green |
| | 13 OC (ATP) | Green | Green | Green | Green | Green | Green |
| | 14 Balise (LEU) | Red | Green | Red | Yellow | Green | Red |
| | 15 Point | Green | Green | Green | Green | Green | Green |
| | 16 Track Segment / Axle Counter | Green | Green | Green | Green | Green | Green |
| | 17 Signal | Red | Green | Green | Green | Green | Green |
| | 18 ATP | Green | Green | Green | Green | Green | Green |
| | 19 RBC (Interface) | Green | Red | Red | Yellow | Green | Red |
| | 20 Civil Works | Green | Green | Green | Green | Green | Yellow |
| | 21 Cabling | Green | Green | Green | Green | Green | Green |
| | 22 RBC | Green | Red | Red | Yellow | Green | Red |
| Other | | | | | | | |
| | 23 Labour | Green | Green | Green | Green | Green | Green |
| | 24 Indirect Costs | Red | Green | Green | Green | Green | Green |
| | 25 Maintenance ¹⁾ | Red | Green | Green | Red | Red | Green |
| | 26 Ground comms | Green | Red | Green | Red | Green | Red |
| | 27 Possession/Disruption | Red | Red | Red | Green | Green | Red |
| | 28 Test Trains | Red | Red | Red | Green | Green | Green |
| | 29 Works to Adjoining Control Centre | Red | Red | Green | Green | Red | Red |
| | 30 Contract Preliminaries | Red | Red | Red | Green | Red | Red |
| | 31 Contract Overheads and Profit | Red | Red | Green | Green | Green | Red |
| | 32 Escalation | Red | Red | Green | Green | Green | Red |
| | 33 Contingency/Risk | Red | Red | Green | Green | Green | Red |
| | 34 Training | Red | Red | Red | Green | Green | Green |
| | 35 Spare Parts | Red | Red | Red | Green | Green | Yellow |
| | 36 Track Alterations (IRJ) | Red | Red | Green | Green | Green | Green |
| | 37 Sunk Costs | Red | Red | Red | Green | Green | Green |
| | 38 Telecomms Works | Red | Red | Green | Green | Green | Green |

¹⁾ if not included in Labour (i. e. spare parts)

= item is not included
 = item is partially included
 = item is not included

Figure 2: Cost calculation matrix (part 1)

Compared to the technical items fewer similarities can be seen within the cost comparison matrix part 2. Items like relationships with private train operators, project architecture (hub, spoke, etc.) or integration with other disciplines are only regarded by single railway partners. A general statement of this matrix is that NetworkRail regards most items for cost calculation. The overview of cost calculation matrix part 2 is shown in Figure 3.

| | | ADIF | Banverket | DB | Network Rail | ProRail | RFI |
|------------------------------------|-----------------------------------------------------------------------------------------------|-------|-----------|--------|--------------|---------|-------|
| Extraordinary efforts | | | | | | | |
| 1 | Cross border connections | Red | | Red | Green | Green | Red |
| 2 | Environmental aspects | Red | | Yellow | Green | Red | Red |
| 3 | Integration with other disciplines | | | Yellow | Green | Green | Red |
| Marketplace characteristics | | | | | | | |
| 4 | Specific standards | Red | | Green | Green | Green | Green |
| 5 | Contractual aspects (i.e. risksharing) | Green | | Red | | | Green |
| 6 | Portion of internal activity | Red | | Red | Green | | Red |
| 7 | Design Development | | | | Green | | Green |
| Others | | | | | | | |
| 8 | General project risk (Currency risks, laws and regulations, organisational issues, etc) | | Green | Yellow | | Green | Green |
| 9 | Relations with Privatised Train Operators | | | Red | Green | Green | Red |
| 10 | Hub and Spoke project | | | Green | Green | Green | Red |
| 11 | Turnkey Project | | | Yellow | Red | Green | Green |
| 12 | Greenfield | | | Red | Red | Green | Green |
| 13 | Brownfield | | | Red | Red | Green | Green |

| | |
|--|------------------------------|
| | = item is not included |
| | = item is partially included |
| | = item is not included |

Figure 3: Cost calculation matrix (part 2)

4.2 Presentation of Cost Calculation Approaches

The partners either consider cost drivers with a nominal value or multiplying total cost with a surcharge factor. RFI is doing most easy calculation as they sum up values from tables and pricelists and increase this amount by multiplying with a surcharge factor for uncertainty. The other partners are doing in a first step a rough calculation based on a scheme plan to get an indication about the height of the investment. Later on in the workflow the calculation is more exactly. Banvernet is doing an analysis of former projects to identify the cost drivers and evaluate them with a probabilistic method to find the best value. DB Netz and ProRail split up their calculation by technical cost drivers and calculate the effective values, then labour, testing and specific standards as cost drivers are added. NetworkRail is using a matrix showing percentages to calculate a surcharge to consider cost drivers. ADIF does not have a standardized process for cost calculation now. Currently cost calculation is done by experienced experts on an individual basis. For the nearer future a structured cost calculation method will be implemented. The cost calculation approaches of all INESS railway partners are explained below. All information has been delivered and verified by each partner.

4.2.1 DB Netz Cost Calculation Approach

At DB Netz the calculation of signalling projects is split into two phases. Within the first phase a rough estimation of costs is made by using a cost calculation tool, which is being introduced in the following descriptions.

In early project stages (i.e. phase 1 according to German HOAI) first calculations can be made with a limited number of input values like the number of signals and points and some inputs from a draft version of the scheme plan. These calculations are based on existing (frame) contracts with OEM's and suppliers, mean values of past projects and forecasted values for resource intensive components (e.g. copper for cabling).

Later in the project (i.e. phase 3 according to German HOAI) the detailed calculation is made based on an overall subdivision regarding all components of the signalling system. Values like the number and size of buildings as well as the length of necessary cabling are included in the detailed calculation more precisely.

For the calculation of the signalling system within the early project stages the system is divided into the following six chapters:

- Signal
- Buildings / Installations
- Telecommunication
- Level Crossings
- Electronic Installations
- Other Trades

Signal

The chapter “Signal” is the basis for calculation result. This chapter contains the most parameters for calculation (see Figure 4). The number of SEU’s and the market segment of the project have the biggest influence on calculations. Other parameters are the share of already existing infrastructure for electronic interlockings and the specific regulatory framework for the project. The regulatory framework mainly impacts the calculated project duration. Required ETCS-Level, areal dimensions as well as number and design of the required stations within the interlocking are taken into account.

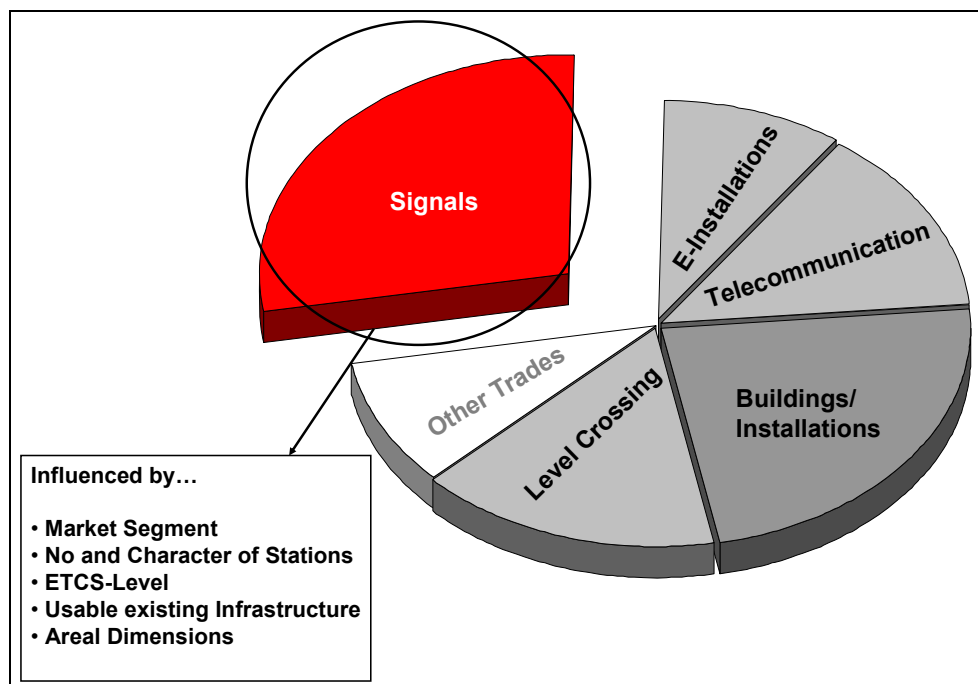


Figure 4: Example - Influences on the chapter “Signals”

The subchapter “Signal” is divided into two parts, the “Signalling System” including the interior fittings as well as field elements like the signals, switches, interfaces to the level crossings and “Power Supply” with UPS. Further components are the Automatic Train Protection (ATP) and (if applicable) Command and Control System (CCS; see Figure 5).

Buildings / Installations

Derived from the number of SEU’s the DB-Calculation-Tool generates a value for forecasted costs of buildings and installations. Bases for this value are calculations from empirical project data sets and supplier guidelines.

Telecommunication

Costs for telecommunication equipment are calculated based on the scheme plan and on topographic dimensions of the signalling system. Mean values from about 50 projects build the basis for the calculations.

Level Crossings / Electronic Installations

For level crossings and electronic installations blanket values based on mean values are taken into account by the DB-Calculation-Tool.

Other Trades

Project specific extra efforts can also be considered by the cost calculation tool. I.E. decommissioning of obsolete track infrastructure or removal of redundant passing lines are itemised here. In relation to the overall budget this chapter of the calculation tool in general considers less than five percent.

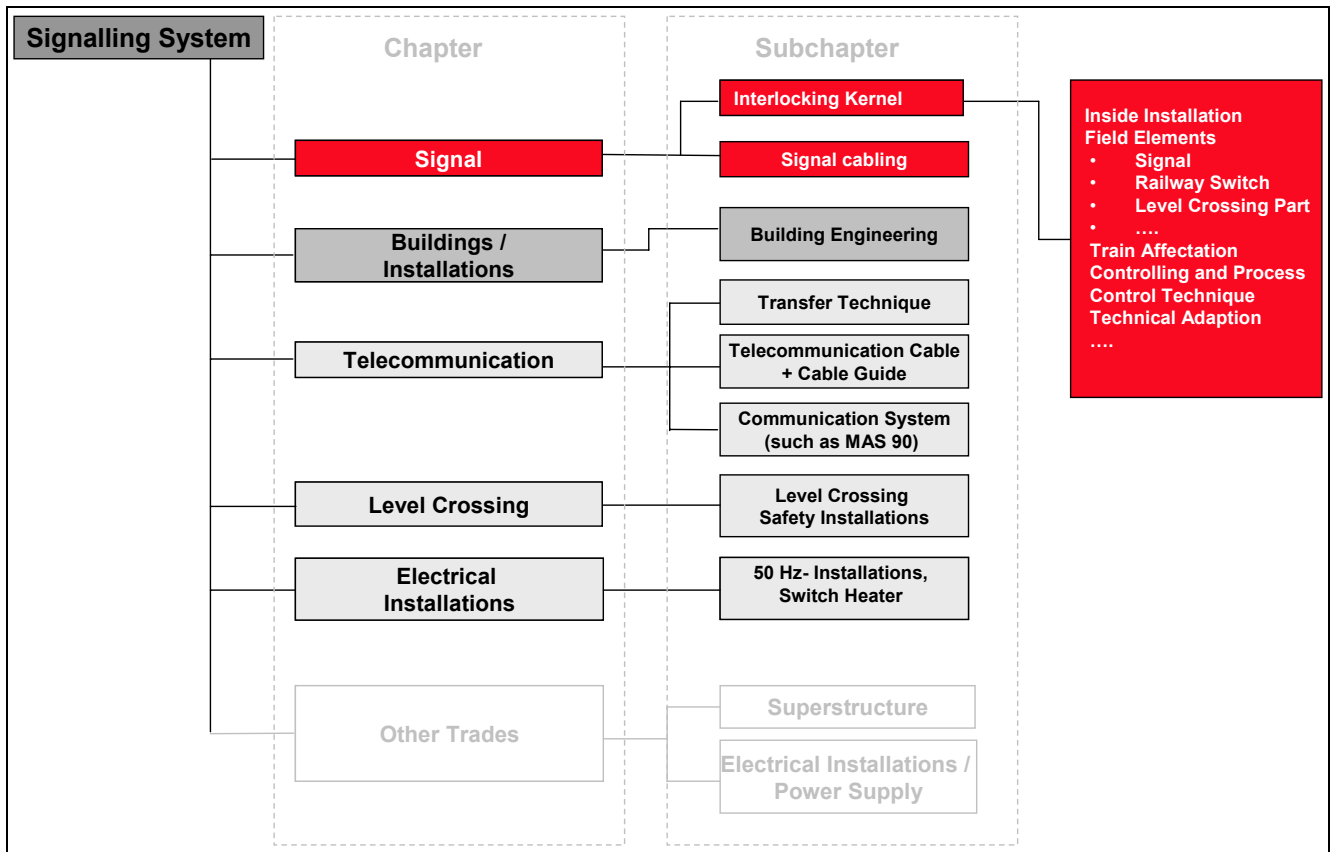


Figure 5: Chapters and subchapters of the DB-Calculation Tool

4.2.2 Banverket cost calculation Approach “Lichtenberg Method”

In the Swedish Market cost calculation for interlocking projects is practiced by using the Lichtenberg Method as a structured approach. After several projects have not been staying in their budget frames Banverket has introduced this method for modelling costs. The focus is on an enhanced understanding of the key issues, assumptions and risks that are involved during the project. The Lichtenberg Method is structured in three stages: “Qualitative Assessment”, “Quantitative Assessment” and “Action”. Cost calculation is a central point in the second stage of the approach. Depending on the estimated overall project volume the Lichtenberg Method is only partially applied. E. g. in case of small and medium projects not the complete effort described in the three stages is made.

The stages are passed through by a multi-disciplinary analysis group involving participants with different and antithetic perspectives on the project. Guided by a neutral facilitator participants can - among others - represent the roles of a generalist and a specialist, optimist and pessimist, economist and technician. Besides the roles it is important to include participants with the right expertise within the analysis group. Passing the three stages of the Lichtenberg Method the analysis group has to consider different issues as primarily the task (signalling system project), the client organization, the business environment, human and technical issues as well as economic and financial issues.

Stage 1 “Qualitative Assessment”

In the first stage “Qualitative Assessment” of the Lichtenberg Method different project specific characteristics are described and documented. The description is subdivided into the following three parts:

- Purpose
- Project World
- Scenarios

The “Purpose” of the project is pointed out with a description of project aims, objectives, conditions and a definition of quality parameters. Relevant aspects for signalling projects can be – among others - public needs (e.g. traffic complexity), the number of SEU’s involved, if the project is a reinvestment or new technology, the architecture of the project (centralized/decentralized), responsibility for telecoms and cabling.

After working out the “Purpose” of the project, circumstances are specified. At this point also issues from the purpose definition can be relevant. In the “Project World” key issues and influences associated with the project are worked out by the participating project experts.

Within the last part of the “Qualitative Assessment” different scenarios about the course of the project are specified by the analysis group. At this point of time the most important variables to be monitored are named.

Stage 2 “Quantitative Assessment”

For the “Quantitative Assessment” the most important variables from past projects are analysed and classified. Result of the past projects analysis is an overview of the key uncertainties to be expected during the new interlocking project. Afterwards the different uncertainties are classified by the analysis team according their controllability. The outcoming uncertainty profile shows uncertainties in order of priority. This information is used to specify the most uncertain items in more detail, to guide the decision maker and to set the management priorities. An exemplary pie chart with possible uncertainties in an interlocking project can be seen in Figure 6.

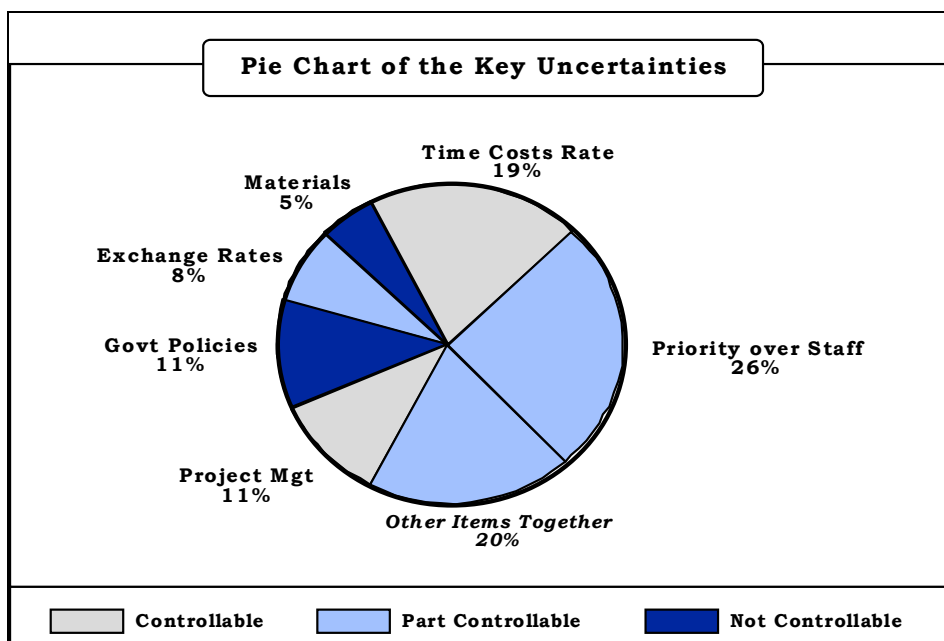


Figure 6: Possible uncertainties within an interlocking project

Many of the key project values, like the project duration, project costs or costs for subprojects, can be measured by operating figures. One task in the stage Quantitative Assessment is to estimate the probability for achieving the scheduled values. Based on a mean value the possible out coming values are forecasted by the analysis group. An exemplary distribution of the project length is shown in Figure 7.

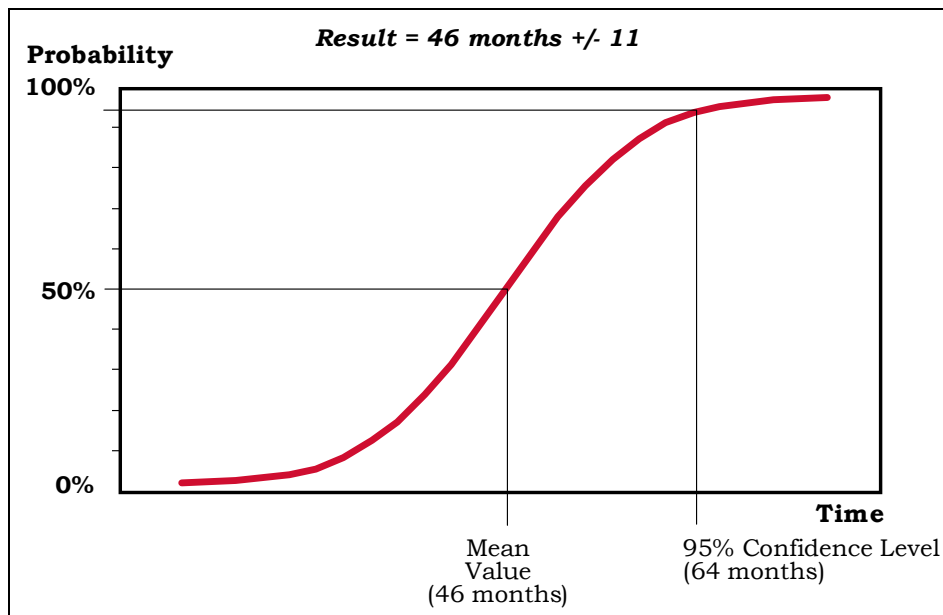


Figure 7: Probability distribution of the project length

Project costs are estimated by using the triple estimate. The analysis group therefore has to assess three possible values. The first is the extreme minimum of project costs which is expected with a probability of one percent. The second value is the most likely, expected with the highest probability. The last value, as well with a very low probability, is the cost maximum. Following a typical probability distribution, feasible costs are displayed as Figure 8 shows.

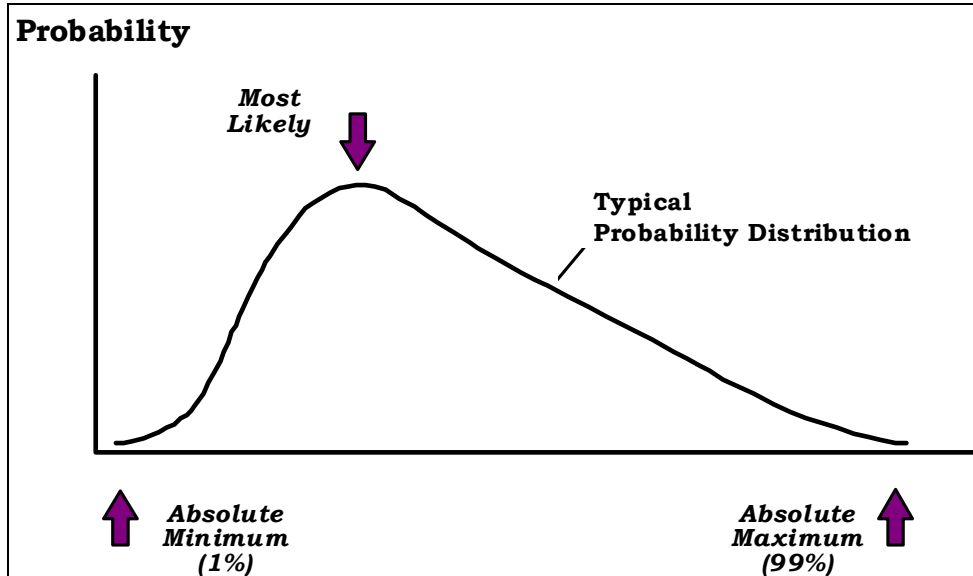


Figure 8: Definition of the triple estimate

Deduced from the resulting values of the triple estimate time schedules and budgets for the interlocking project are planned.

Stage 3 “Action”

Within the last stage of the Lichtenberg Method concrete action plans connected with milestones and responsibilities are established. Regarding cost calculation there are no relevant points in this stage.

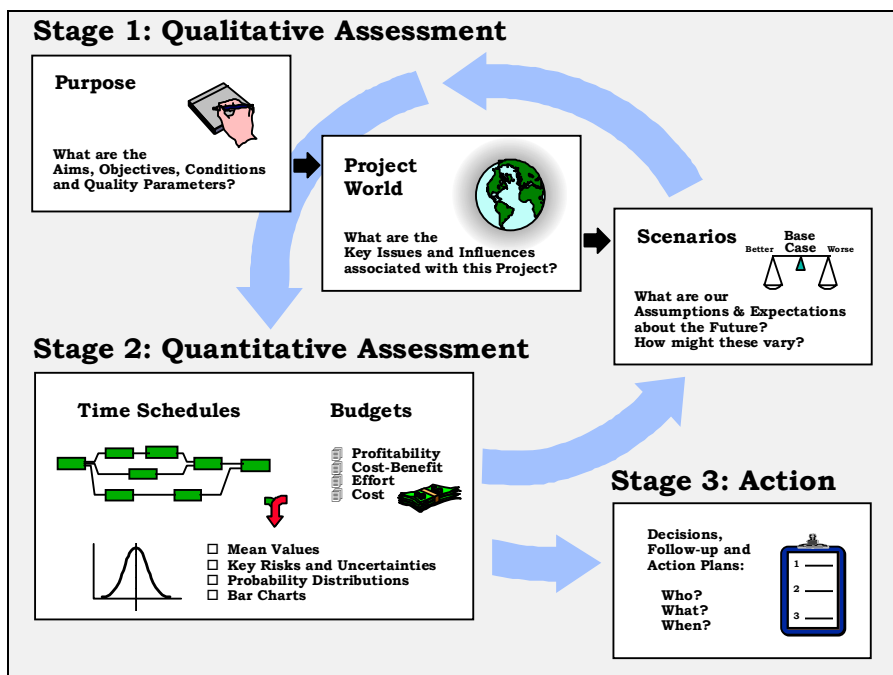


Figure 9: Three stages of the Lichtenberg Method

4.2.3 ProRail Cost Calculation Approach

Introduction

This chapter describes how ProRail determines investment costs during the project development process. Project and planning risks are also taken into consideration within this process. At the beginning of each project the project team is named. This team consists of the project manager as the team leader, a rail systems engineer, a leading cost engineer (in multi discipline projects one of the cost engineers leads the internal process) and the tender manager. The determination process for investment costs (in this process overview the project example is a signalling project with a value above 3 million Euros) at ProRail consists of four stages. In the first stage the project team defines the project scope by describing the technical requirements, collecting ideas for improvement and solutions for open questions from the development department. With these inputs the design plan can be established as also explained in stage 2. The design plan is leading into the cost report, worked out by the cost engineer to obtain the needed budget. Preparation of the cost report will also be explained in the stage 2. When the cost report has run through several stages the cost engineer will review the finalized cost report together with the project manager to check before presenting the report to the investment committee in the approval stage number 3. The investment committee has to decide either to go on or to cancel the project. Once the investment committee has approved the project, the tender manager starts developing the contracting plan (plan which describes the contracts and its clauses) as the first stage in the tendering process.

Stage 1 - Planning

First stage in the workflow is the planning. The members of the project team are compiling data to establish the preliminary design plan for the first cost calculation in stage 2 of the workflow. Cost calculation is explained in the next stage. The preliminary design plan is based on a scheme scratch containing limited information about:

- Total length of tracks
- Number of SEU's
- Additional requirements regarding power supply, housings, type of signalling system, etc.

Experience from former projects and technical developments are considered and flow into the planning as well. The preparation of the cost report is the last part of the planning stage. The result of the cost calculation process, being a part in the whole project management process, will be the cost report. Purpose of the cost report is to get the budget for the project approved. The preparation of the cost report starts already in the planning stage of the project as the outcome of this stage is the base for the cost calculation in the second stage.

Stage 2 - Cost Calculation

The cost engineer prepares the cost report using the probabilistic model. Applied rates for each single work package and costs for capital assets are based on the Rail Case Base and/or dedicated tooling. Rail Case Base is a ProRail owned database containing standard costs from a single signal to a double track bridge. Database is fed with frame contracts and actuals from former projects. Only a limited group of employees, granted access by management, is allowed to use the Rail Case Base as this data is very sensitive. Every selected employee needs to attend to an one day training before accessing the Rail Case Base for the first time. This training will end in a final test to verify the learned skills in order to make sure that the database will be used in a proper way. A Rail Case Base operating licence will be handed out to each participant passing the test successfully.

There is dedicated tooling available for cost calculation of the signalling part of the project only. The cost calculation model for signalling is valid only for relay based or electronic interlockings.

Calculation for the cost report is realized with the following formula:

- i) Number of cost drivers multiplied with estimated/standard rates based on Lowest (L), Standard (T) or Top (U) of the cost range.

Main cost drivers are:

- Technical items (signals, train detection, point machines or any other field objects)
- Interlocking costs based on number of SEU's and type of technology
- Labour, Testing
- Specific Standards

- ii) Capital expenditures (own and contractor expenses, engineering) are added as a percentage of main cost drivers
- iii) Variation in number of cost drivers
- iv) Project risk allowance

The cost report is calculated during stage 2 in three levels of specification (see Figure 10):

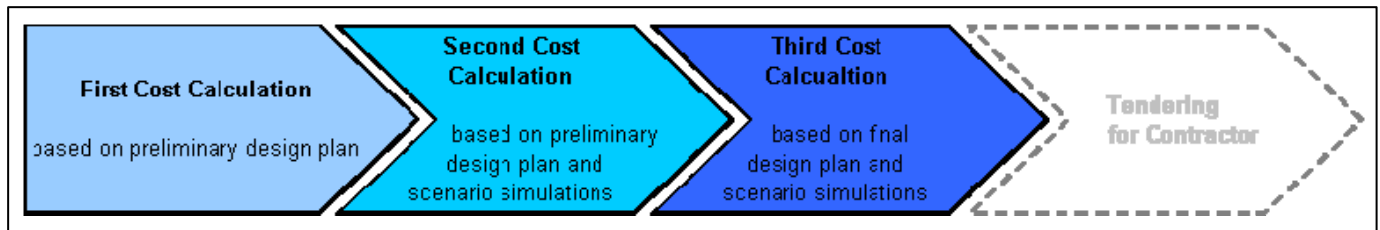


Figure 10 – Cost Report Calculation Phases

The first cost calculation shown in Figure 10 is based on a preliminary design scheme to get an indication about the amount of the investment. The second cost calculation is using the preliminary design scheme and simulating different scenarios leading to a more precise budget. The third cost calculation is done with the final design plan and simulation of different scenarios to fix the budget. This final budget will be the project cost baseline determining the approval workflow for the investment. It will as well be used as an input for the tendering process. Actual costs will be tracked versus the project baseline to show possible deviations in budget. It is necessary to add risk allowance to the project cost in order to have complete and consistent budget estimation. The nominal value to determine the average project risk allowance is calculated using Monte-Carlo-Method. Monte-Carlo-Method also called MC-Simulation is a method from stochastic mathematics, where an experiment is performed by changing variables many times (in ProRails case: 10,000 drawings). These results are evaluated by using probabilistic theories to get the most probable value. Three different types of price sets (worst/average/best) and the variety in number of cost drivers (or field elements) in the project are considered within the ProRail calculation method. The scenarios are calculated 10,000 times in order to create a histogram for identifying the most probable value and a standard deviation for budget determination. This most expected value is called μ ("mu") and the standard deviation is σ ("sigma"). μ is the base for the budget model. Five percent of the μ is added on top of the overall budget to have a safety buffer for future uncertainties. σ is

considered as 50% over and 50% under. If it is necessary to have a more precise budget, the cost expert needs to recalculate by using a more limited σ (2σ leads to 30% over/under).

Stage 3 - Approval

The cost report is presented to the investment committee. This committee advises the Board of Directors (and in limited cases the Supervisory Board) in regarding legitimacy, efficiency and effectiveness of the presented investment by taking their decision based on planning aspects, resources availability, benefits, costs and politics. In general, decisions for renewals of signalling systems are taken much quicker than for new lines as there is more time needed to discuss all relevant aspects like profitability of the invested capital.

Stage 4 - Tendering & Contracts

At this stage the tender manager is responsible for a contact plan. This plan specifies the exact number of contracts in this project, the contractual clauses and estimated budget. Based on financial volume of the project this plan needs an approval by the tender board (two members of the Board of Directors of ProRail and Head of the Procurement department).

All scheme plans, technical drawings, engineering and – in a later stage – technical tender documents for the contractors is done by external engineering bureaus in case of relay based interlockings. In case of electronic interlockings the engineering of the interlocking will be done by the supplier instead of an engineering bureau. All other aspects will be done by the engineering bureau. The scope of the supplier will be as limited as possible due to the strategic context.

In case of an electronic interlocking a technical specification document and a approved design scheme is necessary to minimize opportunity costs, which would result out of multiple time-wasting technical discussions with each single participant of the tender. Having one approved design enables to compare the contractor's bids. It will also make sure that all safety and environmental regulations will be observed. The bids of the suppliers will be evaluated versus the project cost baseline for the identification of the best supplier. Once the contract is awarded after finishing the tendering process, the supplier starts manufacturing relating to given technical specification. In the tender process of electronic interlockings besides the realisation also the maintenance tendered. These maintenance contracts are SFA/SLA (Service Framework Agreement / Service Level Agreement) based. These maintenance contracts will be renegotiated every 5 years.

4.2.4 NetworkRail Approach

Introduction

This chapter describes how Network Rail estimates investment costs for signalling systems during the project development process. In this process business risks and cost tracking versus the defined base spend are considered. Like many organisations, Network Rail’s investment processes are defined in a set of instructions called “The NR Investment Regulations”. Network Rail also has an eight stage project development process defined in a set of procedures called “GRIP” – Guide to Railway Investment Projects, from which much of this data is extracted.

ROLES & RESPONSIBILITIES - RACI/Product Matrix

The RACI/Product Matrix (**R**esponsible, **A**ccountable, **C**onsult, **I**nform) in Figure 11 shows responsibilities for each single stage of the project cost estimation process. Columns are indicating the 13 roles participating in this process. Each role is allocated to a specific job function. With the RACI/Product Matrix responsibilities, rights and duties can be clearly assigned to the effected personnel. Single roles may not be involved in every stage. Responsibilities, rights and duties can also be split and allocated to several roles. Visualization enhances the sense of duty and motivates the effected personnel. This ensures a smooth work flow and avoids misunderstanding. The several stages of the cost estimation process, shown in the column “Products” of Figure 11 will be explained in the subchapter II in detail.

| Key: | Roles | | | | | | | | | | | | |
|---------------------------------------|--------------------|-----------|---------------------|-----------------|-----------------------------|----------------------------|------------------|-----------------|--------------|----------------------|---------|----------|-------------------------|
| | Estimating Manager | Estimator | Senior Cost Analyst | Project Planner | Principal Quantity Surveyor | Programme Controls Manager | Project Engineer | Project Manager | Risk Analyst | Risk & Value Manager | Sponsor | Engineer | Contracts & Procurement |
| Responsible | | | | | | | | | | | | | |
| Accountable | | | | | | | | | | | | | |
| Consult | | | | | | | | | | | | | |
| Inform | | | | | | | | | | | | | |
| Products | | | | | | | | | | | | | |
| Estimate Registration Form | CI | C | | | | | | RA | | | | RA | |
| Stage 1 - Order of Magnitude Estimate | A | R | CI | CI | C | CI | C | CI | C | C | I | R | |
| Stage 2 - Outline Budget | A | R | | CI | C | CI | C | CI | C | C | I | | |
| Stage 3 - Quantified Estimate | A | R | | CI | C | CI | C | CI | CI | CI | I | | I |
| Stage 4 - Definitive Estimate | A | R | | CI | CI | CI | C | CI | CI | CI | I | | I |
| Stage 5 - Detailed Estimate | A | R | | CI | CI | CI | C | CI | CI | CI | I | | I |
| Project Profile Baseline Report | R | C | CI | C | CI | CI | C | C | C | C | I | | I |

Figure 11: RACI/Product Matrix

Products

Estimate Registration Form

The Estimate Registration Form is created at the beginning of the process and requires sponsor's and project manager's input. This form shall describe project details, list of key personnel and key milestones. Furthermore a summary of estimate requirements and available inputs are included. These inputs are necessary for the preparation of the estimate and to manage the cost estimation process.

Stage 1 – Order of Magnitude Estimate

The purpose of an Order of Magnitude Estimate is to provide an early indication of likely cost of a project, based on limited project definition and sparse inputs. This type of estimate is primarily used to support business planning. The goal of this stage is to define the project's strategic objective and to evaluate the strategic business case. At this stage the estimate is extremely rough. In order to prepare the estimate as accurate as possible the direct cost shall be referred to similar existing projects included in the Network Rail estimating database. Indirect costs are evaluated with percentages. Other costs, not considered as direct or indirect, are included for completeness as well. Minimum input to initiate the Order of Magnitude Estimate Process is:

- Sponsors Remit
- Development Remit
- Estimate Registration Form

The estimate is structured according to the generic Work Breakdown Structure (WBS) and coded to the Cost Breakdown Structure (CBS). Each single item of the WBS is priced using unit costs or unit rates from the NetworkRail Work Item Catalogue (NR-WIC), containing the following:

- Signed Estimate Executive Summary
- WBS Report to Level 1
- CBS / Project Profile Report
- Indication of Source
- Schedule of assumptions and exclusions
- Source Details of all quantities

Either the project manager, engineer or estimator may prepare this estimate. These persons have to consider the risk and contingency referring to GRIP document PM10 – Risk Management, in order that the levels of risk implicit in the estimate can be considered.

Stage 2 – Outline Budget

The purpose of this stage is to specify the cost estimation of stage 1 in order to have a reasonable base to move forward with the project. All possible options have to be considered to take strategic decisions. Therefore the following documents are required:

- Estimate Registration Form
- Functional Specifications
- Project Plan
- Stage 1 Estimate

The format of these documents is structured in accordance with the WBS- and CBS-standard. Each cost item is evaluated with NR-WIC standard rates. Same documents as in stage 1 are included. They are just updated with the latest figures.

- Signed Estimate Executive Summary
- WBS Report to Level 2
- CBS / Project Profile Report

- Indication of Source
- Schedule of assumptions and exclusions
- Source Details of all quantities

Costs, scope and risks are now broken down into initial structures in terms of cost drivers, which facilitates managing the project financially. An initial understanding of the overall engineering and operating requirements (as applicable) is established at this stage and strategic risks are identified.

The forecasted demand of man hours from estimator’s assumption are multiplied with unit rates from NetworkRail or their external consultant. Applied rates are found in the estimating database. Similar projects are used as reference as well. A percentage allowance is added to this simple calculation. These percentages are at the estimator’s discretion. The reason for the percentage allowance is to have a safety buffer for unexpected events in this phase of scheme. Basis for the mentioned allowances are the estimated direct costs. The percentage used to calculate the allowances is at the Estimator’s discretion. Direct costs are priced using the estimating database or similar projects. The indirect costs are determined by calculating a percentage from direct cost. Percentage matrix (Figure 12) can act as indicative.

| Asset | Prelims | Design | Test & Commission | Network Rail Management | Sponsor |
|-----------------------|----------------|---------------|------------------------------|--------------------------------|----------------|
| Signalling | 35 - 40% | 10 - 30% | 10 – 15% | 6 - 15% | 2 - 5% |
| AC/DC Electrification | 20 - 25% | 3 - 10% | 5 – 10% | 6 - 15% | 2 - 5% |
| Permanent Way | 20 - 30% | 3 - 10% | 2 - 5% | 6 - 15% | 2 - 5% |
| Telecoms | 25 - 35% | 5 - 10% | 5 – 15% | 6 - 15% | 2 - 5% |
| Property Projects | 15 - 25% | 5 - 15% | N/A | 6 - 15% | 2 - 5% |
| Level Crossings | 35 - 40% | 5 - 10% | 5 - 10% | 6 - 15% | 2 - 5% |
| Bridges | 20 - 35% | 5 - 10% | N/A | 6 - 15% | 2 - 5% |
| Tunnels | 20 - 35% | 10 - 15% | N/A | 6 - 15% | 2 - 5% |
| General Civils | 15 - 25% | 10 - 15% | N/A | 6 - 15% | 2 - 5% |

Figure 12: Indirect Cost Matrix

Other costs need to be contained as already identified in stage 1. An allowance for inflation shall be included in accordance with the guidance note for the calculation of project inflation allowances. Especially for projects with a duration over 1 or 2 years the guidance note for the calculation of project inflation allowances, issued by the head of estimating, can be used as guide. All other costs like possession allowance costs, network change compensation costs, transport and work costs, town planning, land purchases costs and qualitative risk assessment shall be requested from NetworkRail’s respective teams, departments or shall be in accordance with effective standards.

| | Project Stages | | | | | |
|-----------------------|----------------------|-----------------------|--------------------------------|----------------------|-------------------------------------------|----------------------|
| | 2 Pre-Feasibility | 3 Option Selection | 4 Single Option Development | 5 Detailed Design | 6 Construction, Testing and Commission | 7 Scheme Handback |
| % of project duration | 10% | 20% | 30% | 50% | 90% | 100% |
| % of spend | 1% | 2% | 4% | 18% | 60% | 15% |
| % of spend cumulative | 1% | 3% | 7% | 25% | 85% | 100% |

Figure 13: Matrix Inflation Calculation

Stage 3 – Quantified Estimate

Objective of this stage is to gather an effective means of the evaluated project solution options in support of value engineering whilst maintaining the ability to deliver the expected outputs in compliance with NR's obligations as a main line Infrastructure Manager. The estimate is based on approximate quantities of work items. Each item is priced by using the estimating system cost data, suppliers' estimates and forecasted cost resources. The outline business case is clearly defined. In order to fulfil the objective, this stage is requiring input from:

- Previous Stages
- Project Design Specifications
- Option Selection Report
- VM2 or VM3 study
- Project Plan
- Possession Strategy

A detailed working plan showing approximate quantities for each item structured the WBS and coded in accordance with CBS. Each item will be evaluated with cost rates from NR-WIC. The quantified estimate contains:

- Signed Estimate Executive Summary
- WBS Report to Level 3
- CBS / Project Profile Report
- Indication of Source
- Schedule of assumptions and exclusions
- Source Details of all quantities

The estimate preparation shall be based on a reasonable level of detail, at this stage. Allowances and costs calculated in estimate stage 2 shall be updated with the latest figures or replaced with actuals if available.

Stage 4 – Definite Estimate

An accurate view of each single option is provided to support the tendering process. This is based on previous stages output and updated reporting, planning and strategy. Furthermore, it enables to track the cost in a proper way according to the financial standard. The difference to stage 3 is, that there is a firm quantified working plan now available including:

- Signed Estimate Executive Summary
- WBS Report to Level 4
- CBS / Project Profile Report
- Indication of Source
- Schedule of assumptions and exclusions
- Source Details of all quantities
- A design which is “approved in principle” – i.e. contains all the necessary information by which the project may be designed in detail and subsequently constructed, and where the outputs to be delivered are defined.

During the feasibility and development phase an estimated cost shall have been established for the design works. As the engineering work has been undertaken direct costs are with suppliers costs or resource based pricing. Indirect costs shall be determined by using predicted time, durations and quantities of resources. Allowances and other costs are updated with quotations or recalculated with latest figures.

Stage 5 – Detailed Estimate

Compared to stage 4 the level of maturity of all work items will be higher and end up into a fixed forecast of baseline cost for procurement and financial purposes. Outcome of this stage is a complete working plan with firm quantities of each item referring to WBS and CBS and priced with unit rates from NR-WIC. Following documents have to be contained:

- Signed Estimate Executive Summary
- WBS Report to Level 5
- CBS / Project Profile Report
- Indication of Source
- Schedule of assumptions and exclusions
- Source Details of all quantities

Project Profile Baseline Report

The Project Baseline Report is included in stage 1-5. This report shows the costs broken down to repeatable work items or standard cost element level of detail. In the moment that implementation authority is sought, the report needs to be finalized.

Input from a validated estimate is needed for the preparation this report. The minimum requirements are a PCAF report completed for each of the types of repeatable work item to be delivered by the project

Workflow – Estimate Production Process

The Estimate Production Process consists of 13 steps shown in Figure 14.

This workflow shall ensure that all affected personnel are informed and aware about the tasks and responsibilities at every stage of the process in order to ensure a smooth flow. All areas of cost which likely arise are considered to allow the authorities to take reasonable strategic financial decisions and to minimize the project management risk.

It allows that all standard procedures are strictly adhered. An accurate documentation and approval of each step are guaranteed for traceability later on. The detailed documentation enables a comparison of actual cost against estimated cost and is helpful for more precise future estimates.

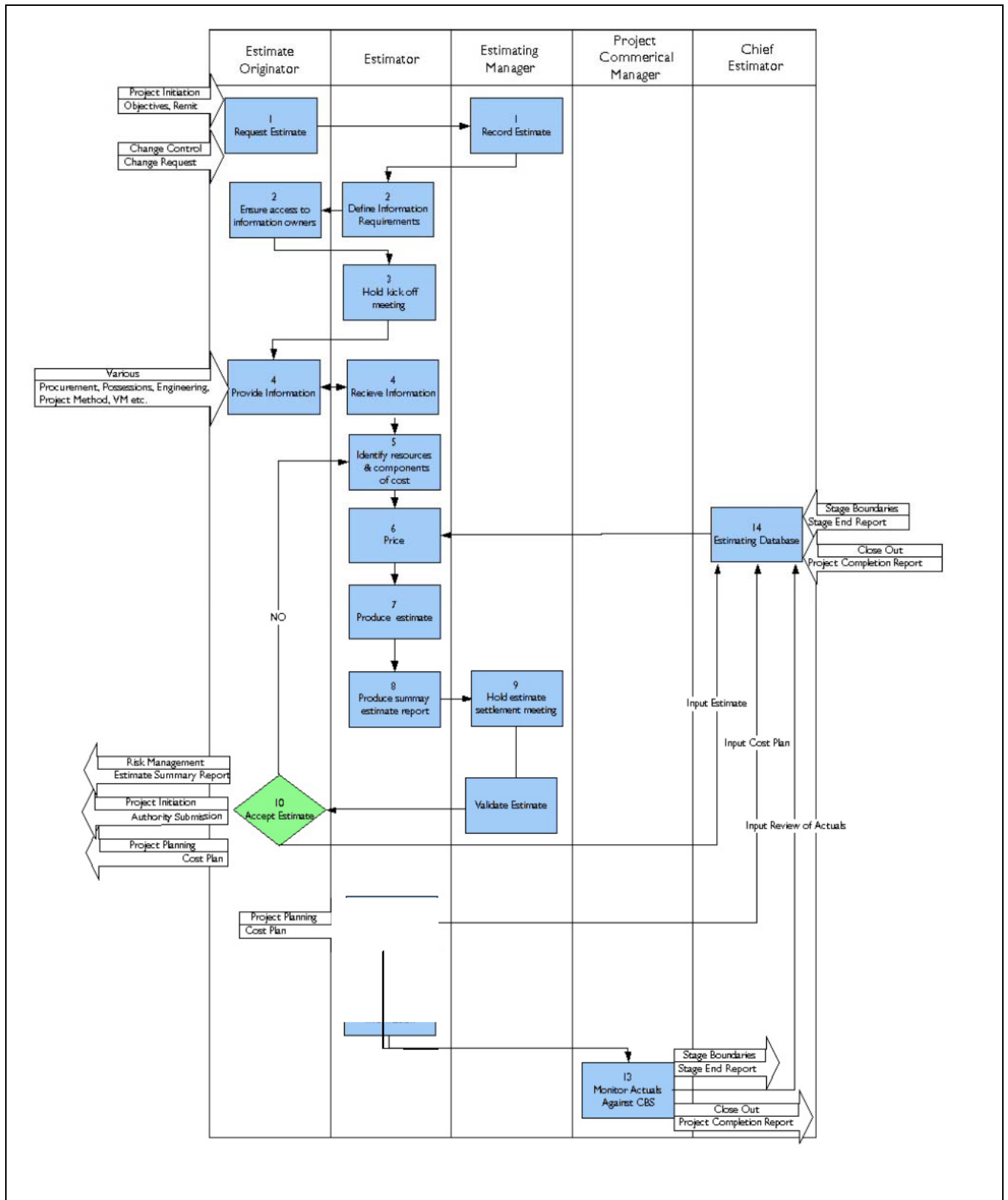


Figure 14: Estimate Production Process

Delivery Phase

During the delivery phase there is a need to monitor the cost budget against expenditure so as to manage the spend profile, calculate the anticipated forecast cost and address cost overrun. Cost estimating and measurement will still be required during this stage with feedback to the business case monitoring process and outturn costs for acceptance and benefit realisation.

Possession Related Implementation Costs

At all stages of a project the estimate shall contain an allowance for the planning and management of possession that the project may require to facilitate the works. Possession costs shall include the following as minimum:

- Protection
- Isolation provision
- TOC compensation
- Transport an Work Acts (TWA) – which arise where NR needs to acquire land outside its existing boundaries, or where the project involves structures extending 10m above or below the existing railway footprint

To establish a budget for protection cost it is recommended that a simple calculation of forecasted man hours multiplied by unit rates is applied for the calculation of Network Rail and external protection costs. The forecasted number of possessions multiplied by a notional unit rate is applied for the calculation of the isolation budget. The most difficult type of isolation may be required shall be used for the calculation. As the TOC compensation allowance is uncertain, it shall be included in pre-feasibility and feasibility estimates and updated if possible. The TWA allowance is uncertain as well, but a provision will be necessary and guidance or advice on the formulation of the allowance can be obtained from headquarters legal and secretariat. Cost from local authorities or for town planning has to be considered and included based on legal departments advice or on actual invoices.

4.2.5 RFI Cost Calculation Approach

Introduction

RFI splits up an interlocking into 2 basic items. The first items are the **field devices**. Field devices are all mechanical devices such as signals and switches. Second item is called **Central Unit Equipment (CUE)**. The Central Unit Equipment is separated into two different subsets. One subset is named **Central Position (CP)** and the other subset **power interface Controllers (Contr)**. The Central Position contains man machine interface, communication system and the logical elaboration unit. The logical elaboration unit elaborates the interlocking safety software and acts as an interface to other systems like external line block, RBC, Traffic Control System, ect.). Figure 1 below shows the schematic layout of the interlocking.

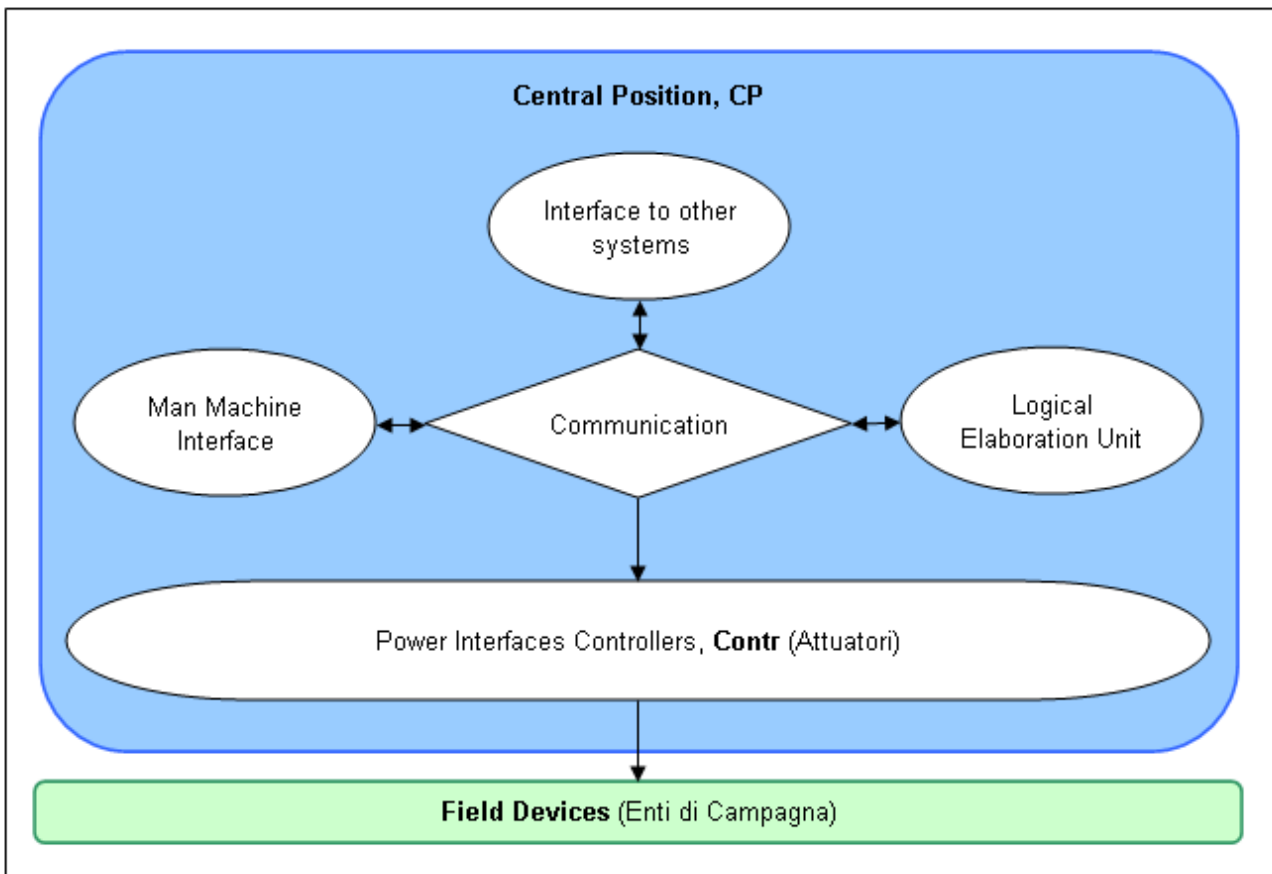


Figure 15 – Schematic layout of Central Unit Equipment

As every supplier has its own system, it may happen that hardware and the amount of needed hardware differs from already installed interlocking to interlocking such as the used software.

Since every interlocking has always got the same functions, RFI does not consider the architecture of an interlocking.

Cost Calculation

RFI is doing separate calculation for Central Unit Equipment Value (CUE_Value) and field devices. Once both costs have been determined, they will be summed up.

Central Unit Equipment Value Calculation

The CUE_Value is calculated with following formula:

$$CUE_Value = (CP_Value + Contr_Value) * (1 + \sum_i K_i)$$

CUE_Value is the sum of the Central Position Value and Controller Value multiplied with a complexity factor to add a surcharge to consider uncertainties.

The calculation is done in three steps and described in the following:

STEP 1 – Central Position Value (CP Value)

The cost of an interlocking depends on the complexity of the station it manages, e.g. quantity of switches. Therefore RFI introduced 5 types of basic interlockings. Each type has a specific value which is considered for the calculation. The figure below gives an overview about the different types. First and second column shows all criteria which has to be considered. All the other columns are reflecting the amounts of each criterion and are the decisive factor to choose the correct interlocking size. The value in the last line will be used in the calculation.

| Interlocking Sizes | | SIZE 1 | SIZE 2 | SIZE 3 | SIZE 4 | SIZE 5 |
|-------------------------------|--------------------------------|---------------|---------------|---------------|---------------|---------------|
| TC | TRACK CIRCUITS (TC) | 14 | 39 | 58 | 72 | 101 |
| SW | SWITCHES (| 7 | 14 | 22 | 36 | 54 |
| BSS | BLOCKING SWITCH SYSTEMS | 18 | 36 | 57 | 70 | 95 |
| I/O | I/O CONTROLS | 24 | 24 | 51 | 72 | 101 |
| SIG | NO. SIGNAL LIGHTS (High & Low) | 14 | 41 | 72 | 87 | 101 |
| # field elements | | 77 | 154 | 260 | 337 | 452 |
| Central Position Value | | u EURO | v EURO | x EURO | y EURO | z EURO |

Figure 16 – Matrix interlocking sizes

STEP 2 – Controller Value

RFI uses a calculation table as shown in figure 3 to determine the Controller Value. First column lists all required types of controllers. Second column reflects the standard costs for each controller. The column “Quantity” needs to be filled out with the amount of controllers needed. The product of the value with amount of controllers gives the total value per type of controller and the sum of all total values reflects the Controller Value. Column reference shows in which assembly group it is used.

| Description of controller | Value € | Reference | Quantity | Total Value € |
|-----------------------------|---------|-----------|----------|---------------|
| Indicator di direzione | v EURO | * | # | = v EURO x # |
| Segnali strada da PL | w EURO | * | # | = w EURO x # |
| Consensi elettrici generici | x EURO | * | # | = x EURO x # |
| Dispositivi MPL | y EURO | * | # | = y EURO x # |
| ... | z EURO | * | # | = z EURO x # |
| Total Contr Value | | | | Σ |

| | |
|-------------------|--------------------------------|
| <u>Reference*</u> | |
| TC | TRACK CIRCUITS (TC) |
| SW | SWITCHES |
| BSS | BLOCKING SWITCH SYSTEMS |
| I/O | I/O CONTROLS |
| SIG | NO. SIGNAL LIGHTS (High & Low) |

Figure 17 – Contr_ Value calculation table

STEP 3 – Complexity Factor K_i

The complexity of the interlocking is evaluated with complexity factor K_i . This factor is added as a surcharge and includes influences of potential cost drivers like number of switches, presence of automatic convergence protection, lifetime of the contract and number of software reconfigurations, needed for different steps of commissioning. The corrective factor is the sum of three different sub-factors. The following table shows the different types of complexity factors. Each factor displays a certain percentage which has to be chosen respecting the effective criteria. Please be aware that either K_1 or K_2 is used for calculation.

| K_i | Type | % |
|--------------|---------------------------------------------------------------------|------------|
| K_1 | Number of switches | |
| | ≤ 35 | x% |
| | $36 < x \leq 50$ | x% |
| | ... | x% |
| K_2 | Presence of automatic convergence protection | |
| | use either K1 or K2 ! | x% |
| K_3 | Life time of the contract (years) | |
| | $2 \leq x < 4$ | x% |
| | $x = 4$ | x% |
| | $4 \leq x < 5$ | x% |
| | ... | x% |
| K_4 | Number of sw reconfiguration for different steps of schematic plane | |
| | 2 | x% |
| | 3 | x% |
| | ... | x% |
| Total | | $\Sigma\%$ |

Figure 18 – Complexity factor K_i

Field Devices

All field elements are standards. Therefore RFI uses a list with standard cost for the field elements and construction works. As there is an executive design available, RFI looks up the cost for the required field devices and construction works in the standard costs. At the end each single cost items need to be summed up to get the total cost for the field devices.

Final Calculation

After determining CP_Value, Contr_Value and complexity factor K_i as described, they will be inserted in the formula ($CUE_Value = (CP_Value + Contr_Value) * (1 + \Sigma_i K_i)$) and the final cost will be calculated. The sum of CUE_Value and the value for the field devices are the total project cost.

4.2.6 ADIF - Cost Calculation Approach

The process is initiated, if there is a need to take an action on a station or in a section of the network. This need can be caused by technical (obsolescence of the installation, adequacy of the facilities, excessive number of failures, etc.) or by strategic issues (affectation of a new line of high speed, extension of a core of suburban lines, etc.).

Once the need is specified the next step is to look for a technical solution to solve the issue. Based on the current design and necessary changes (elimination of a telephonic block, modernization of the assets, installation of the ERTMS system, etc.) of the asset, engineering experts will propose a more suitable technical solution in accordance to the needs. The proposal contains the following chapters:

- Substitution of obsolete signalling system
- Block lines
- Points
- Cabling
- Civil works
- Track circuits (or axle counters)
- Power supply for signalling
- Incorporation of the signalling system in the CTC
- Installation of ground and mobile communications
- Signals

The next step is to estimate the capital expenses for the changes to the existing or the new installation. This calculation is done by the same engineering experts that have prepared the technical proposal as they are aware of the requirements and specifics (type of area, availability of technical buildings, power supply availability, state of the cabling, etc.).

The estimate is done based upon previous projects with similar technical equipment and requirements in order to have a unitary design of the lines and also comparable cost information for future projects.

Sometimes assistance for the design of the signalling system from consulting companies or suppliers is needed, if the signalling system is very complex or specific. As they prepare the proposals for technical solutions, they also provide a detailed cost calculation.

Currently there has been no tool developed for cost calculation, but expected to be implemented in a short time.

Section 5 – CONCLUSIONS

5.1 Relevant items for cost calculation

Outcome of the comparison between the cost items of each partner (see figure 2 – cost calculation matrix (part1)) is that the partners considered nearly the same cost items under technical point of view with three exceptions (Balise (LEU), RBC interface and RBC). These three items seem to have particular characteristics causing a special treatment for cost calculation. Almost nobody included other cost items except labour cost. NetworkRail is covering the cost items very detailed. A final conclusion from cost calculation matrix part 1 is that every partner considers the capital expenditures and labour cost directly linked to the investment and the follow-up cost are not considered in these calculations.

5.2 Cost calculation approaches

Comparing the methods of each partner for cost calculation generally contain the three basic steps Planning – Cost estimation – Implementation. Contrary to this the cost calculation approaches differ a lot. The cost calculation approaches were established based on the various experiences and adjusted to the needs of each partner. Some of the partners like DB Netz, NetworkRail and RFI maintain huge databases containing historic cost for a large number of items. There have been two calculation methods become apparent. One method is including the uncertainty of the cost driver development by using a surcharge calculation and the other one is based on probabilistic models like ProRail does. Contrary to the surcharge calculation

are the probabilistic models giving the most expected costs. Project features specially focussed within cost calculation are project length, supplier contract length, complexity of the interlocking and geographical risk. This leads to a probable cost driving character of these features.

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