Appendix L: Cost Forecasting Methodology

Bonneagar Iompair Éireann
Transport Infrastructure Ireland

METROLINK

MetroLink

Cost Forecasting Methodology

Document Control Information

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Abbreviations

Abbreviation	Definition
APM	Association for Project Management
CESSM	Civil Engineers Standard Method of Measurement
CKBS	Chandler KBS
DoT	Department of Transport
EIA	Environmental Impact Assessment
GMP	Guaranteed Maximum Price
HSE	Health Service Executive
IPA	Infrastructure and Projects Authority
IRM	Institute of Risk Management
J/I	Jacobs / Idom
NTA	National Transport Authority
QCRA	Quantitative Cost Risk Analysis
QSRA	Quantitative Schedule Risk Analysis
QRA	Quantitative Risk Analysis
RCF	Reference Class Forecasting
RPA	Railway Procurement Agency
SBC	Scheme Base Cost
TII	Transport Infrastructure Ireland
T&T	Turner & Townsend
TPCE	Total Preliminary Cost Estimate
WBS	Work Breakdown Structure

Table 1 – Abbreviations

1. Executive Summary

Context

Large and complex transport projects suffer from considerable uncertainty and risks which often change the circumstances in the way a project is developed and delivered. This has resulted in significant cost overruns in some cases. Eight out of ten past metro projects had cost overruns. Overruns of up to 50% are common, and overruns over 50% are not uncommon. Nearly one in three metro projects exceeded their cost estimates by more than 50%.

The purpose of this paper is to:

- Summarise the issues in respect to overruns in large projects;
- Confirm what standards and guidance will be used to support the cost forecast for the MetroLink project; and
- Confirm the cost forecast and risk techniques available to test the cost forecast.

Cost Forecasting Techniques and Guidance

To provide greater confidence in developing the robust cost forecast, both TII and NTA have engaged the services of three cost advisors Jacobs / Idom – London Bridge Associates (LBA), Turner & Townsend (T&T) and Chandler KBS (CBS) in preparing the Scheme Base Cost element of the Total Preliminary Cost Estimate (TPCE).

The Scheme Base Cost estimates will be developed in accordance with the National Transport Authority (NTA) Cost Management Guidelines for Public Transport Projects, and the Transport Infrastructure Ireland (TII) Project Services Group Cost Estimating Procedure. Where possible depending on the development and detail of the current preliminary design and where applicable the quantification of the works will be carried out in accordance with Civil Engineering Standard Method of Measurement 4 (CESMM4). The Scheme Base Cost (SBC) estimate will be prepared using a combination of benchmark and first principles methods using actual and historic cost data.

The National Transport Authority (NTA) Cost Management Guidelines for Public Transport Projects also stipulate the requirement for a Quantitative Risk Assessment (QRA) technique to be adopted in the development of the risk aspect of the cost forecasts. The three cost advisors will collectively participate in the QRA process with TII and NTA. The QRA will be used to forecast risk exposure to provide an allowance to cover the potential impact of risk events occurring and identifying key areas of risk to focus TII management attention. Prior to the initiating the QRA, TII needs to consider its risk appetite which is discussed later in the report. On recent projects TII has utilised the P80 output (80th percentile of confidence) to establish project risk exposure via the Quantitative Risk Analysis Process and it intends to utilise the P80 output for the MetroLink Cost Forecast and for the Preliminary Business Case, however, will review the P30 and P50 outputs also.

Both the Scheme Base Cost and the QRA are based on an ‘inside view’ of the project. The estimation approach breaks the whole of works down into work packages. The work packages are then estimated with regards to cost, schedule and risk and summed up to arrive at a project level estimate. Therefore these ‘inside view’ estimates are likely to include a range of biases.

Validation of estimated costs

Reference Class Forecasting is an established method to address the root causes of cost and schedule overruns in projects. These root causes, namely optimism bias and political bias can lead to underestimations of projects' costs and schedules, which can later result in cost and / or schedule overruns. Reference Class Forecasting is a method of seeking an 'outside view' and is used as a means of validating and assuring the project budget / schedule. Reference Class Forecasting uses historic data of similar completed projects. Thus, a Reference Class Forecast takes a top-down approach in respect to cost, schedule and risk forecasting. The Reference Class Forecast involves three steps: (1) compile a Reference Class of past, similar, completed projects; (2) establish the distribution of the variables in question in the Reference Class; (3) compare the 'inside view' and 'outside view' estimates and identify the potential level of biases depending on the risk appetite of decision makers. The Reference Class Forecast helps to predict the final cost of the MetroLink project.

Utilising the Reference Class data and breaking it down further in to asset classes (e.g., tunnels, stations etc.) will aid the cost comparison between the bottom-up estimate approach (Scheme Base Cost and QRA) and the top-down approach (RCF). The Reference Class data and associated asset classes have been mapped to the Scheme Base Cost - Cost Breakdown Structure (CBS) to aid the review.

Finally, Expert Judgement will be applied to determine whether a suitable approach and methodology has been applied to develop the Total Preliminary Cost Estimate and an appropriate risk and contingency assessment has been developed and included for MetroLink.

Recommendation

Combining forecasting based on inside and outside views and expert judgement for the MetroLink project ensures the project uses industry-recognised, best-practice cost forecast methodologies. This will help to define a robust cost forecast for the MetroLink project. This will enable Government decision makers, at the key milestones of the project, to make informed decisions on whether to proceed to the following phase gates and through to the implementation of the project.

2. Foreword to MetroLink Cost Forecasting Methodology

We have heard time and time again of governments spending more on infrastructure than they told taxpayers they would. Yet, there has been little in the way of informed debate about understanding and curing underlying or root causes.

Announcement of premature cost estimates undermines the decision-making process. There is a tendency to seek early cost estimates at a stage when little information is available. Premature announcements haunt projects for years as they anchor later-stage cost forecasts. This is to the detriment of accurate forecasting and informed decision-making. Forecasts must be de-biased and must use the best available data. They should also reflect the risk appetite of the decision makers.

There is also a tendency to hang onto unreliable forecasts that have not been subjected to rigorous due diligence of a wider range of proven methodologies used in forecasting megaprojects.

TII is committed to jettisoning unreliable forecasts and applying a more robust approach to forecasting the cost, schedule and benefits of MetroLink in the interest of presenting the best available information to decision makers before a commitment to invest scarce public funds in this transformative public infrastructure is made.

Three key questions must be answered. Is the project economically viable? Is the project affordable? What project budget and timeline should be set? To answer these questions, project sponsors and funders should use probabilistic forecasts – considering the full range of outcomes – instead of single point forecasts to capture this reality. Conventionally, the simplest form of a probabilistic forecast is a forecast for the best case, most likely case and the worst case. Decision makers must be presented with a realistic forecast statement of risks, costs and benefits at key decision points. In the case of MetroLink, the first key decision point is the approval of the Business Case. This occurs prior to making the Railway Order. The second is the approval of the updated Business Case prior to entering main works contracts.

We commit to sound analysis and planning of infrastructure and to making decisions with broad social and economic benefit. We must avoid announcing project costs before they have been properly assessed. Understated costs, for whatever reason, makes it impossible for decision-makers to differentiate good projects from bad.

Producing reliable cost forecasts is vital. Current international cost estimation guidance is inconsistent, omits valuable tools, and not all draw sufficiently on previous projects because of the inconsistency or scarcity of relevant data. We strive to address shortcomings of previous practice.

We learn from experience. Our infrastructure systems should promise what is worth having, and then deliver what is promised. We should settle for nothing less. This document presents TII's thinking on the methodology to be adopted to increase accuracy in forecasting costs.

The Cost Forecasting Methodology is in line with the provision in the Public Spending Code 2019 in that it applies the new project life cycle and reflects leading practice in this field in Ireland and internationally.

3. Cost and schedule overruns in metro projects: international experience

According to recent research nearly eight out of ten metro projects have cost overrun. The study shows that overruns of up to 50% are common, and further shows overruns over 50% are not uncommon. Nearly one in three metro projects exceeded their cost estimates by more than 50%. (See table 2)

	Average	*Median*	*Range*	*Frequency of overrun*	*Sample size (n)*
Cost overrun	+47%	+31%	-46% to +1016%	77%	189
Schedule overrun	+55%	+29%	-16% to +410%	63%	43

Table 2 – Cost and schedule overrun in metro projects

Overrun affects private as well as public sector projects, and trends are not improving; the frequency of overruns have remained constantly high for the 30-year period for which comparable data exists. Geography also does not seem to matter; projects in all countries and continents for which data are available suffer from overruns.

2.1 Comparison with other transport infrastructure projects

The above study shows that the average cost overrun on metro projects (47%) is statistically greater than the cost overruns in roads, bridges and non-urban rail projects (24%, 27% and 29% respectively). The frequency of cost overrun in transport infrastructure projects is comparable, where 8 out of 10 projects have experienced cost overruns. Table 3 below captures both cost and schedule overruns in roads, bridges, tunnels and non-urban rail projects.

The average schedule overrun in metro projects is 63%. The study shows that the schedule risk of metro projects is similar to that of all other transport projects (within a range 50%-71%).

	Cost (mean)	*overrun Frequency cost overrun*	*Schedule overrun (mean)*	*Frequency schedule overrun*	*Sample size (n)*
Metro	+47%	77%	+55%	63%	189
Roads	+24%***	72%	+20%	71%	1834
Bridges	+27%***	64%	+23%	68%	96
Tunnels	+38%	73%	+22%	50%	75
Rail	+29%***	70%	+25%	56%	257

****p < 0.0001; **p < 0.01, * p < 0.005 (p-values based on difference between metro projects and other project types using two-sample Wilcoxon tests)*

Table 3 – Metro projects compared to transport infrastructure projects

4. Process to define cost forecasting methodology

In most recent years, there have been several publications, which have identified lessons learned in cost forecasting methodology. TII have completed a comprehensive study on this and detailed some of the findings below.

Lack of sufficiently comprehensive or robust planning for the process to establish cost forecast

Most recently, as a result of cost and schedule overruns at the New Children's Hospital in Ireland, the Health Service Executive (HSE) on behalf of the government, engaged PwC to carry out a review of the reasons for the cost escalations on the project and document its findings. The following three excerpts have been noted during a review of the report and are relevant to MetroLink.

> *'Significant failures occurred during the crucial planning and budgeting stages of the project. The basis of the original budget was flawed, and risks were understated in the business case'.*
>
> *'The understanding of the risk profile associated with the procurement and contracting strategy was poor at all levels of the governance structure. The capital budget made no provision for the price premium that the public sector would need to pay the contractors to bear the risks transferred to them… As a consequence, the budget significantly underestimated the likely outturn cost. Furthermore, red flags indicating the inadequacy of the budget were missed;'*
>
> *'In our view the €450m increase in projected costs in the NPH Project are attributable to the following areas….:*
>
> 1. *Underestimation: Costs that are a consequence of underestimation, principally during the planning, budgeting as well as set-up stages of the project. In our assessment, €294m (65%) of the cost increase can be attributed to issues that should have been identified prior to the approval of the DBC. It includes, for example, the price of risk transferred to the subcontractors that was insufficiently priced as well as costs that would have been absorbed by the inclusion of an allowance for optimism bias and a more appropriate level of contingency;'*

The UK Department of Transport and the Infrastructure and Projects Authority (IPA) have also published lessons learned following the issues they experienced with a range of major projects and the Northern Line, Thameslink project and Crossrail in particular; the following captures the most relevant to the MetroLink project as it sets to define its Cost Forecasting methodology.

Set a realistic cost envelope

> *Lesson A4.2 Set a realistic cost envelope – "Establish a full cost envelope based on reference class data or benchmarking and include adjustments for optimism bias. Identify explicit de-scoping options in case early affordability issues emerge after supplier prices become available. Report projected outturn costs with percentage confidence indicators against the target cost and total budget envelope."*

Test value for money through benchmarking

> *"Lesson C2.1 Test value for money through benchmarking – "Collect and review cost data across government and use cross-sectoral and international comparisons for common cost items. Challenge the delivery organisation and its supply chain to evidence their cost estimates. Ensure this evidence employs both top-down and bottom-up benchmarking to test value for money." (Infrastructure and Projects Authority)*

Refrain from early announcement of cost envelopes

A key component to the accuracy of the cost forecasting methodology is the consideration and approach to risk-based estimating. In Australia the Grattan Institute has also previous published its own report following cost overrun and over expenditure on transport projects within the previous 15 years. A key factor they attribute to political bias.

> *'Ministers and opposition spokespeople often promise to build a road or bridge or rail line, for a particular cost. They are especially prone to doing so in the lead-up to elections…*
>
> *… It is normally premature and unwise to announce project costs this early in the planning process. History shows that projects with costs announced prior to a formal budget commitment experience far larger cost overruns than projects with later cost announcements. Over the past 15 years, 74 per cent of the total value of cost overruns is explained by the 32 per cent of projects with early cost announcements'* (Grattan Institute)

Use a combination of techniques for cost forecasting including Expert Judgement

In the same report the Grattan Institute also highlights the importance of robust risk-based estimating, combining both, a bottom-up and top-down approach, to gain a reliable and comprehensive assessment.

> *'There is no single "right" way to measure risk, but for an approach to risk measurement to be considered complete, it must be both reliable and comprehensive. Assessments of project risks can be considered:*
>
> ***reliable** if expert opinion is used to tailor risk estimates to projects' specific characteristics, and objective information is used to counter the challenges of optimism bias and strategic misrepresentation; and*
>
> ***comprehensive** if known, unknown, moderate and extreme risks are all accounted for.*
>
> *No single risk measurement tool achieves all these objectives, which means that a combination of tools is required.* Table 4 *on the following page summarises how each risk measurement tool can, if used* (Grattan Institute)

Attributes of each risk management tool, where ✓ indicates that a tool can be used satisfy the criteria, (✓) indicates that a tool can be used to get part way towards the criteria and ✗ indicates that a tool cannot be used to achieve the criteria.

			Reliable		Comprehensive			
			Tailored	Objective	Moderate	Extreme	Known	Unknown
Expert judgement	Expected value		✓	✗	✓	✓	✓	✗
	Probability pricing	Moderate (*e.g.* P50)	✓	✗	✓	✗	✓	✗
		High (*e.g.* P90)	✓	✗	✗	(✓)	✓	✗
	Sensitivity analysis		(✓)	(✓)	✗	✗	✓	✗
Monte Carlo simulation	Expected value		(✓)	(✓)	✓	✓	✓	✗
	Probability pricing	Moderate (*e.g.* P50)	(✓)	(✓)	✓	✗	✓	✗
		High (*e.g.* P90)	(✓)	(✓)	✓	(✓)	✓	✗
	Value at Risk		(✓)	(✓)	✓	✓	✓	✗
Reference class forecasting	Expected value		✗	✓	✓	✓	✓	✓
	Probability pricing	Moderate (*e.g.* P50)	✗	✓	✓	✗	✓	✓
		High (*e.g.* P90)	✗	✓	✗	(✓)	✓	✓
	Value at Risk		✗	✓	✗	✓	✓	✓
Characteristics of complete risk measurement			✓	✓	✓	✓	✓	✓

Source: Grattan analysis.

Table 4 – Complete approaches to risk measurement satisfy all the conditions for reliability and comprehensiveness by using a combination of tools

Finally, the publication by the Infrastructure and Projects Authority, Improving Infrastructure Delivery, Project Initiation Route map, Risk Management Module outlines how QRA and RCF are techniques being used together to quantify the risk and inform the allocation of contingency.

> *'At the outset of the project, there will be many uncertainties and opportunities for the project to evolve along a number of different routes. At this stage RCF approach is more appropriate. As the project nears completion, the 'bottom up' approach will be more applicable, as there will be detailed information available about most aspects and few remaining uncertainties.'*

As a project develops through its phase gates and the definition of the design matures, it is good practice to review both approaches (RCF / QRA) however at any one point one of the approaches will dominate. Figure 1 below shows the project lifecycle and shows the change in approach aligned to the greater degree of definition and maturity of the project.

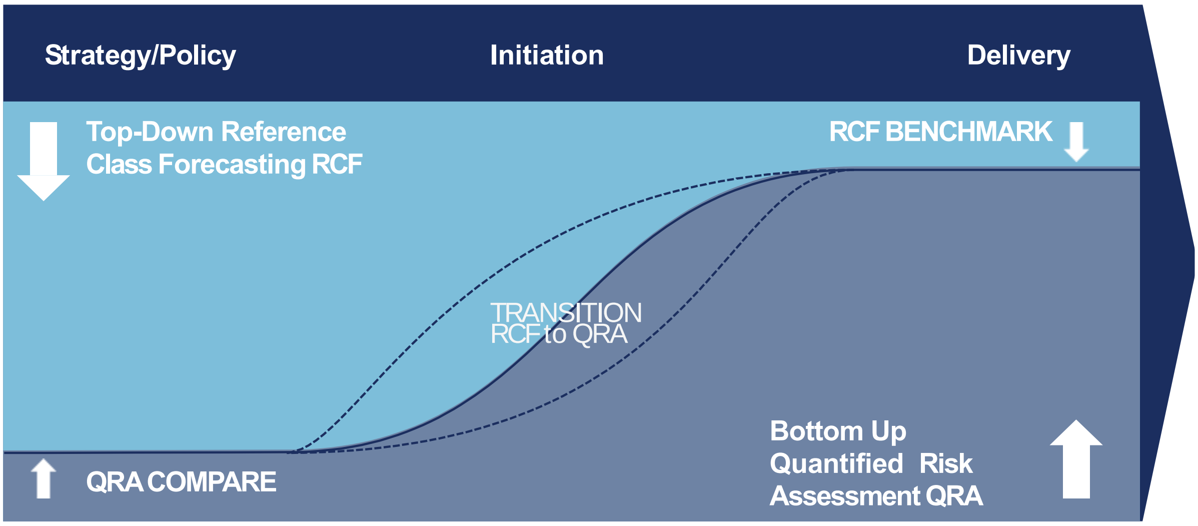


Figure 1 – Risk Assessment and Estimating mathodologies as the design matures

There a number of common themes running through the publications listed above, including:

- Setting robust cost envelope and accurate budget setting;
- Complete risk approach and definition of risk appetite; and
- De-biased estimates using the best available date.

Considering the high percentage of Metro projects that overrun their budgets and schedules, the scale of these overruns and considering these lessons learned, TII defined a cost forecasting methodology for the MetroLink project to create and support informed decision-making.

5. Process to define the Total Preliminary Cost Estimate

The MetroLink project will follow a multistage approach to forecast costs throughout the design phases as it moves towards the Business Case, consisting of:

- Design development;
- Bottom-up estimates of the Base Cost, verified by three independent cost advisors;
- Quantitative Risk Analysis (inside view);
- Reference Class Forecasting (outside view); and
- Expert Judgement.

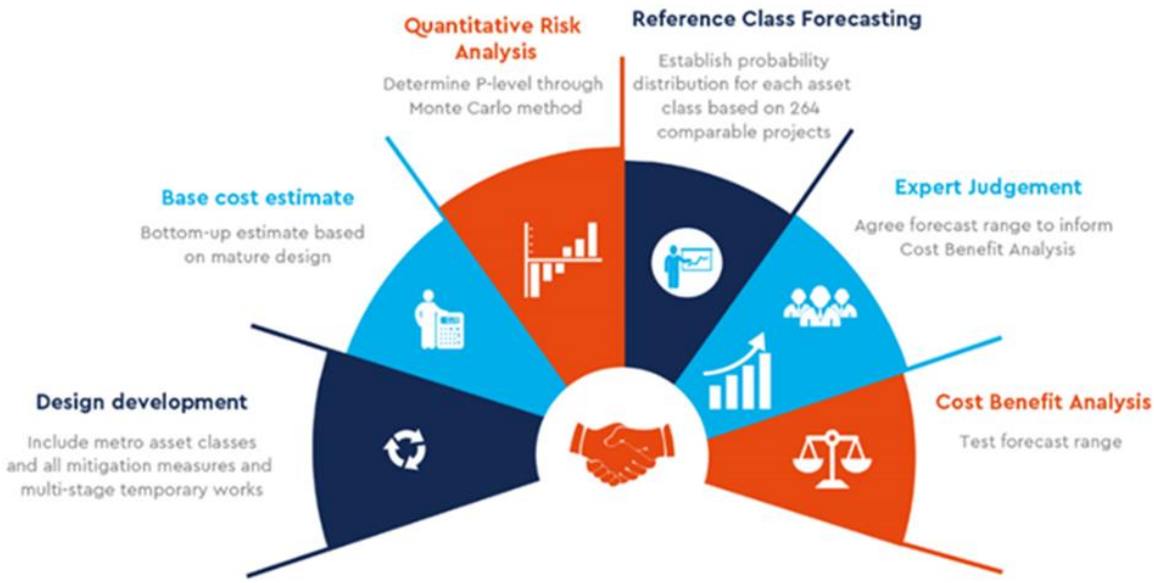


Figure 2 – Multi Stage Approach to forecast cost.

Design development

The Scheme Base Cost estimate is prepared utilising the Preliminary Design which has been prepared by Jacobs / Idom. TII and NTA have engaged the services of three cost advisors Jacobs / Idom – London Bridge Associates (LBA), Turner & Townsend (T&T) and Chandler KBS (CBS) in preparing the Scheme Base Cost element. Each of the estimating parties will individually review and assess the design maturity of the various elements / asset class as part of its estimating process. Following this review, the estimator will propose a ‘price and design’ tolerance level, which will be considered and incorporated into its estimate as it develops and finalises its Scheme Base Cost. A Cost Breakdown Structure (CBS) has been developed based on the current scheme to facilitate the production and review of the estimate.

Industry guidance used to support development of Scheme Base Cost and Quantitative Risk Analysis

The Scheme Base Cost estimate and QRA will be prepared in accordance with the National Transport Authority (NTA) Cost Management Guidelines for Public Transport Projects, dated September 2010 and the Transport Infrastructure Ireland (TII) Project Services Group Cost Estimating, dated May 2013. Where the Preliminary Design detail permits, the estimate will be prepared in accordance with the Civil Engineering Standard Method of Measurement 4 (CESMM4). In addition, the QRA will be developed in line with guidance from the Institute of Risk Management (IRM) and the Association of Project Management (APM).

Process to define the Scheme Base Cost estimate (inside view)

The Scheme Base Cost estimate will be prepared using a combination of benchmark and first principle estimating methods using currently available and historic data (where applicable and uplifted to the base date). The estimate will include allowance for provisional sums and percentage uplifts for items such as preliminaries and insurances.

The Scheme Base Cost estimate will capture the direct works, indirect costs and client costs.

The Total Preliminary Cost Estimate (TPCE) shall capture the Scheme Base Cost plus inflation, contractor and client (employer) risks and contingency and VAT.

The estimate's base date has been set at Q4 2019, escalation to the estimate base date will be required and clearly demonstrated in the estimate build-up where historical rates have been used. Forecast escalation shall be individually assessed however an inflation model and calculator shall also be developed, which will enable an overall inflation index to be developed and used specifically for MetroLink, enabling either a mid-point assessment or a quarterly cash flow assessment. Individual bespoke indices will be developed and applied against specific cost elements and components pre agreed by NTA and TII. The indices contain historic data, dating back to 2008, and will be forecast from the current reporting period to the end of the MetroLink Construction period.

The three cost advisors will interface at various meetings throughout the development of the estimate to agree on a consistent approach on various elements, including Cost Breakdown Structure coverage rules, Indirect Costs, Inflation and Risk. However, each estimate will be prepared on an entirely independent basis.

TII with support from T&T shall develop the Client Cost element of the Scheme Base Cost. Utilising the outline procurement strategy and the MetroLink Consolidated Organisational Design Report a staffing structure shall be developed for the key consultancy packages and assessment shall be made in respect to the other aspects of client cost. These shall be structure into the following headings:

- Planning and Design;
- Client / Sponsoring Agency Costs;
- Client Partner
- Project Delivery Partner; and

- Other / Third Party Costs.

TII shall also develop the Land and Property cost estimate for the scheme, this shall then be validated by Dublin based property consultancy firms, who have a good understanding of the local market and future trends. The assessment of the Land and Property cost estimate shall further have oversight from Transport for London, to bolster experience from an international large transport infrastructure perspective.

Quantitative Risk Analysis (inside view)

Risk is defined as "*An uncertain event or set of circumstances that, should it occur, will have an effect on achievement of one or more objectives.*"

The fundamental aim of Quantitative Risk Analysis (QRA) is to forecast risk exposure which can be used to provide an indication of allowance required to cover the potential impact of risk events occurring and identifying key areas of risk to focus management attention.

The three cost advisors will collectively support the Quantitative Risk Analysis (QRA) process. During the development of the Scheme Base Cost the cost advisors shall individually identify risks and pass them through to TII for incorporation in to the MetroLink risk register. Once the identified risks have been incorporated in to the MetroLink Risk register the three cost advisors, TII and the NTA shall collectively participate in the Quantitative Cost Risk Assessment (QCRA) and Quantitative Schedule Risk Analysis (QSRA).

Discrete risk costs – A discrete risk is an uncertain event with the potential to have an effect on project objectives (negative threats or positive opportunity). This is in essence the output from the quantified project risk register. Discrete risk cost impacts are measured in terms of likelihood of occurrence of cost impact by applying an appropriate distribution of impact range. The cost impact estimates should, where available, be evidence based on impacts from similar projects (historic data).

Estimate Uncertainty (EU) assessment – involves determining the estimate confidence range for each relevant area of the Scheme Base Cost Estimate. This is typically determined by the status / quality of the design and the relevant market testing of rates.

Cost of Schedule Delay – utilising the outputs from the QSRA. Alignment will be reached on what activities / milestones within the schedule best represent the key changes in phases on the project from which the cost of the delay changes from that of the previous (e.g., increase in design team contractor(s) mobilised). The associated cost of delay will be established for each of the agreed project phases, the costs of delay should when available be evidenced based on impacts from similar projects (historic data).

Unknown unknowns – Given the nature of unknown unknowns and the current phase of the project, Preliminary Business Case Stage, it is proposed to adopt a percentage uplift to the Scheme Base Cost, utilising SME judgement and historical data. When considering the uplift consideration should be given to the following:

- The unique nature of the project;
- The potential for standardisation and repetitiveness of the works related to delivery;
- The phase of the project and its associated design maturity;

- Estimating bias within the Scheme Base Cost; and
- Historical analysis of cost overrun and trends.

A recent study from OGP has noted that catastrophic risks, such as the current pandemic, are a challenge for conventional risk identification and assessment. Analysis of the common causes of failures on metro and urban rail projects found that overruns of 100%+ even 400% are caused by non-catastrophic events, which may suggest that these risks can be largely ignored. The QRA will consider some low probability high impact events that have the ability to be assessed as it can provide an indication on the profile of the risk exposure. Albeit it is acknowledged that the QRA might not provide a sufficient allowance should events such as the low likelihood and a high impact. Catastrophic risk (extremely low likelihood and / or extreme high impact) such as the pandemic will be excluded from the QRA assessment. In accordance with the MetroLink Risk Management Plan, any exclusions from the QRA need to be agreed and signed off by the Project Director.

Inflation

Forecast inflation will be assessed by each of the three independent estimating parties and will be calculated using an inflation model. All inflation indices used must be in accordance with recognised practice. The proposed inflation model should be tailored to the local economy and examine construction inflationary / market trends based on historical published data and consider the future economic outlook for the construction sector for the duration of the project. The base cost data date shall be set at Q4 2019. Exchange rate date was confirmed set on 2nd December 2019.

- Each component of the estimate should be assigned an inflation rate to express the cost in the years of expected expenditure;
- The years of expenditure must be based on the preliminary design outline Project Programme which must reflect a realistic scenario, considering project planning and development durations as well as construction; and
- Inflation rates may be different for specific cost elements, but assumptions made in determining the most appropriate inflation rate to use should be clearly identified in the estimate.

VAT

VAT should be forecast at the applicable rates and captured on all element of the Total Preliminary Cost Estimate. The standard VAT rate is currently 23%, however there are elements within the Total Preliminary Cost Estimate that will be eligible for the reduced rate of 13.5%.

6. Reference Class Forecasting (top-down estimate)

In October 2018, TII commenced a collaboration with Professor Bent Flyvbjerg and Dr Alexander Budzier of Oxford Global Projects to support the establishment of a robust cost forecast.

With the assistance of Oxford Global Projects and access to its database of previous similar project outcomes, we will put in place a comprehensive approach to forecasting project costs. This will enable that Government decision makers have the best cost forecast information available to them. When final decisions about the project need to be made, all this information will be included in the Business Case for the MetroLink project. Reference Class Forecasting (RCF) will be used on MetroLink as a method of seeking an 'outside view' and to guard against the effects of biases on projects, which can ultimately result in the underestimation of projects costs and schedules. This underestimation can often result in cost and schedule overruns.

Reference Class Forecasting will be used in addition to the standard TII bottom-up Scheme Base Cost development and QRA process, as a means of benchmarking / validating the project budget / schedule.

A Reference Class forecast (RCF), in the context of MetroLink project, is a forecast which will be utilised to help predict the outcome of the MetroLink project in terms of final cost based on utilising historic data of similar projects (that is, projects in the same 'reference class') to that being forecast. It is believed that the RCF avoid any potential for bias by using information from similar international projects. For the purposes of the MetroLink project, Oxford Global Projects will provide the technical expertise and historic data set to support the RCF process.

The outline process adopted by Oxford Global Projects shall include:

- Selecting the reference class. Identify a sample of past, similar projects;
- Assess the distribution of outcomes and establish the position of the MetroLink project in relation to the outcomes; and
- Assessment of the forecasts and consider what adjustments or further analysis, if any, are required to be made to the MetroLink estimate.

The specific process to be adopted for the RCF for MetroLink is further explained in detail below:

1. TII have responsibility for both national roads and light rail projects. Due to the nature of light rail projects in Ireland, there are a limited number of these and, thus, insufficient projects to form a Reference Class of Irish Projects. Therefore, the historic data (reference class) will be provided by Oxford Global Projects. Oxford Global Projects review and analysis to date has shown that for cost risk metro projects and tunnelling projects have a statistically similar profile and should be pooled. Whilst metro projects and tunnelling projects do not share all the characteristics being exactly alike in terms of scope and nature of the engineering works in terms of their risk profile, they are statistically similar. The overall reference classes for metro projects and tunnelling projects include 264 projects for cost overruns and for 2,451 schedule overruns. For schedule risk the Oxford Global Projects analysis has showed that there are no differences between metro projects and any other types of transport infrastructure projects. Thus, for schedule risk a broad reference class of transport projects will be considered. TII will work closely with Oxford Global Projects to align their asset class data with the MetroLink Cost Breakdown Structure (CBS), enabling the

direct application of the reference class curves to the CBS. The creation of the reference class curves is performed in parallel with the preparation of the Scheme Base Cost estimate and the QRA. It is important to note that the base data for the asset classes must not contain contingency. The data is based on outturn costs for historic projects;

2. Assess the distribution of outcomes and establishing the position of the MetroLink project in relation to the outcomes – e.g., identify the cost overruns of these projects. Figure 3 provides an example of how the cumulative distribution curve of the data (cost overruns) are charted; and
3. Assessment of the forecasts and consider what adjustments or further analysis, if any, are required to be made to the estimates. The Reference Class Forecast will help provide focus on SBC elements (asset classes) such as tunnelling, stations etc., to help further analysis / uplift should the bottom-up estimate (Scheme Base Cost estimate and QRA) not align with the RCF. See figure 3 below. Utilising the same curve, the cumulative percentage of projects now becomes the acceptable chance of overrun. The uplift associated with a specific P-level represents the performance of the projects within the asset class. The decision to apply a certain uplift to achieve a certain level of confidence (P-level) will be taken as part of the process for defining the cost forecast for the scheme and will rely on the bottom-up techniques, on Reference Class Forecasting and on Expert Judgement.

Recent trends in the market suggest that clients who are undertaking large and complex projects are seeking a higher level of confidence and are utilising P90 and P95 in terms of their QRA outputs, however this is completely dependent on the risk appetite of the decision maker.

Oxford Global Projects have prepared a separate study to support TII with their assessment of risk appetite for the MetroLink project, its findings are summarised in the section 7 below.

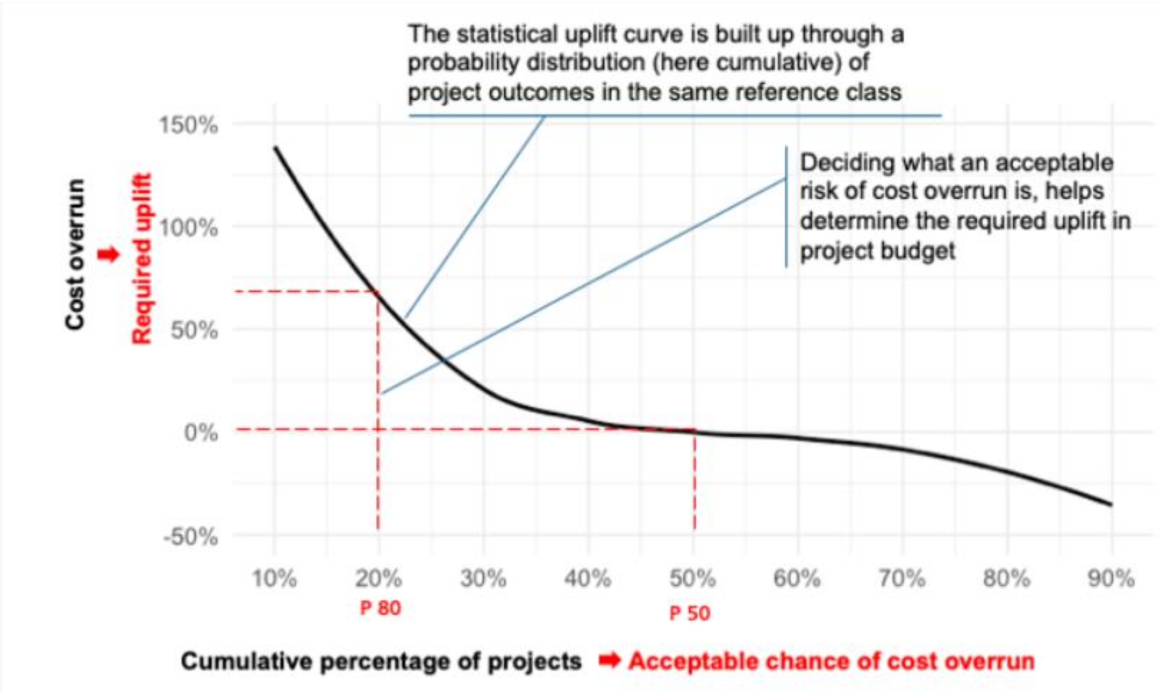


Figure 3 – Establishing the uplift as a function of the acceptable change of cost overrun based on the cumulative distribution of cost overrun in the reference class

Oxford Global Projects produced a number of Reference Class Curves for the MetroLink project, including a general metro curve and 18 asset classes curves. Breaking down the data as shown in Appendix A below helps better understand the data.

The general curve, reflects historic and completed metro and tunnel projects, thus is comparable to the overall risk profile of MetroLink.

A weighted curve for MetroLink has been produced by applying 18 asset classes' curves to the costs of the associated assets. The resulting curve converges closely to the general metro curve in the tail, which is based on client data related to 264 comparable projects.

When defining curves for individual asset classes, Oxford Global Projects used data from the same scope element across all industries (i.e., not only metros and tunnels) that are comparable. This assumes, for example, that road works have a similar risk of cost overrun on earthworks; or that utility diversions have a similar cost overrun than other utility projects like main laying, sewerage works etc.

However, the comparison between the general curve and the summation of the asset class curves shows a gap, this occurs not only in metros but also in other industries (for example nuclear power and decommissioning), which are riskier than others. This gap represents a "metro rail premium", which shows that these projects are generally of higher risk. This is due to factors such as more complex logistics, more difficult locations (e.g., working under and around historic buildings, noise regulation in urban areas, more complex traffic management, more limited number of work phases in station etc.).

For example, a common risk is increasing cost in utility diversions which exceeds the typical cost overrun risk of utility providers' own projects. For this reason, for lower levels of confidence (up to P70) it is prudent to use the general curve based on 264 projects to define the upper bound of the risk and the weighted curve to represent the lower bound.

7. Risk Appetite

Risk appetite is defined as the amount of risk organisation / decision makers are willing to take in order to meet / pursue its objectives.

In the context of MetroLink's forecast of cost, schedule and benefits; the risk appetite will determine the level of certainty sought in the forecast or the inverse the acceptable chance of an overrun for the project. More risk averse organisations seek a higher level of confidence in their estimates and have a lower acceptable chance of overruns.

Current best practice of forecasting provides the full range of estimated outcomes with their respective probability. A P50 cost estimate, for example, means that the project is as likely as not to deliver within that estimate (providing a 50% probability that the overall outturn cost will be greater). A P80 estimate, means that there is an 80% certainty that the estimate will be sufficient and 20% chance that it will be exceeded. A P30 estimate, means that there is an 30% probability that the estimate will be sufficient and a 70% change that it will be exceeded.

Risk appetite and project appraisal

Risk appetite is a key consideration during the front end of projects. Specifically in the project appraisal stage decision-makers ask different questions, which have a different risk appetite:

- Is the project economically viable?
- Is the project affordable?
- What is the cost, time, benefit targets for the project?

Lastly, a key question for every project is setting targets, like budgets and delivery dates. Targets often need to balance risk aversion of decision makers and the economic affordability of large risk amounts. A range of cost forecasts associated with the probabilities from P30 to P80 is deemed by the TII and NTA to provide an appropriate range for cost forecasting and budgeting purposes. The project will utilise the outputs from both the QRA and RCF to support this process.

Range Description	**Cost Forecast**
Management Stretch Target	P30 (Low)
Management Base Target	P50 (Medium)
Prudent Client Appraisal Value	P80 (High)

Table 5 – Preliminary Cost Forecast Range Summary

The range of cost forecasts approach attempts to balance the tension between ensuring that enough funding is available to the projects should they run in to difficulties and at the same time holding projects accountable for their estimates and driving towards better performance, and therefore will be considered in conjunction with the agreement on whether TII changes it risk appetite from the P80 output as typically utilised on its projects.

8. Expert Judgement

The final step in the cost forecasting approach is Expert Judgement. The methodology adopted in the final step of the reference class forecast will include additional analysis of the reference classes to better understand the data, a review of the outliers in the historical data will identify the drivers behind the outliers and whether these drivers need to be considered or disregarded in respect to the MetroLink project. This is where the Expert Judgement comes into effect, because the reference class forecast assumes that MetroLink is as good or as bad as past, historic projects. Reviewing the historical data, learning from the drivers of overrun and assessing these drivers against our detailed knowledge and understanding of the MetroLink project's treatment of risks and opportunities will enable decision makers to identify target ranges that are based on historical data and on concrete plans how to outperform and improve on the performance of past, historical projects. While this Expert Judgement is not disregarding the historical information it helps, building stakeholder confidence in the ability of the project to deliver and calibrates the reasonable level of accepted risk in decisions.

Upon completion of the Scheme Base Cost estimate, the QRA and the RCF, meetings will be convened with the Expert Judgement Group, TII, NTA, Oxford Global Projects and the Project team to review and discuss the outputs and incorporate the Expert Judgement. At the first meeting, TII, the Project Team and Oxford Global Projects shall present the outputs to the Expert Judgement Group, this shall include the Scheme Base Cost, The Independent Estimate Report, The QRA Report and associated Risk Register, The Reference Class Forecast Report, The Construction Programme and the Design Maturity assessment report. The approach and methodology adopted and incorporated are explained to the Expert Judgement Group and it is an open forum to raise queries and gain a greater understand of how the outputs were derived. The Expert Judgement Group are then issued all information to read and review and meet individually as a group to discuss and compare notes and observations. Finally, a feedback meeting is convened to discuss and document their findings and capture any areas for improvement of further works to improve the robustness of the Total Preliminary Cost Estimate or to help minimise risk as the project moves through the next design phase. The Expert Judgement Group also confirm whether they are satisfied that the approach and methodology adopted is what they would expect to see at this stage of the project and confirm it aligns to industry recognised practice.

9. Cost Forecasting for MetroLink

The following figure 4 shows in a diagram how the whole cost forecast process will be performed.

The Scheme Base Cost will be prepared in the first instance, as mentioned above both TII and NTA have engaged the services of the three cost advisors to help deliver a robust Scheme Base Cost estimate. Once received, TII will carry out its own initial comparison between the estimates where significant cost differences are noted to greater understand the reasoning behind the forecasts.

The Quantitative Risk Analysis (QRA) and the Reference Class Forecast (RCF) can be developed in parallel with each other. The three cost advisors, NTA and TII will support the development of the QRA, and Oxford Global Project (Oxford Global Projects) will assist in the application of the reference class data and associated distribution curves.

The project team and TII will hold a structured workshop to review the outputs from both the bottom-up cost forecasting process and the top-down cost forecasting process and using Expert Judgement will record any specific project factors (e.g., environmental factors) that may exist that would lead to the project being either more or less risky than the Reference Class. The project team and TII will decide, considering the outcome of the above, the appropriate cost forecast to be used for the Preliminary Business Case. The discussions, considerations and adjustments should be documented for governance and assurance.

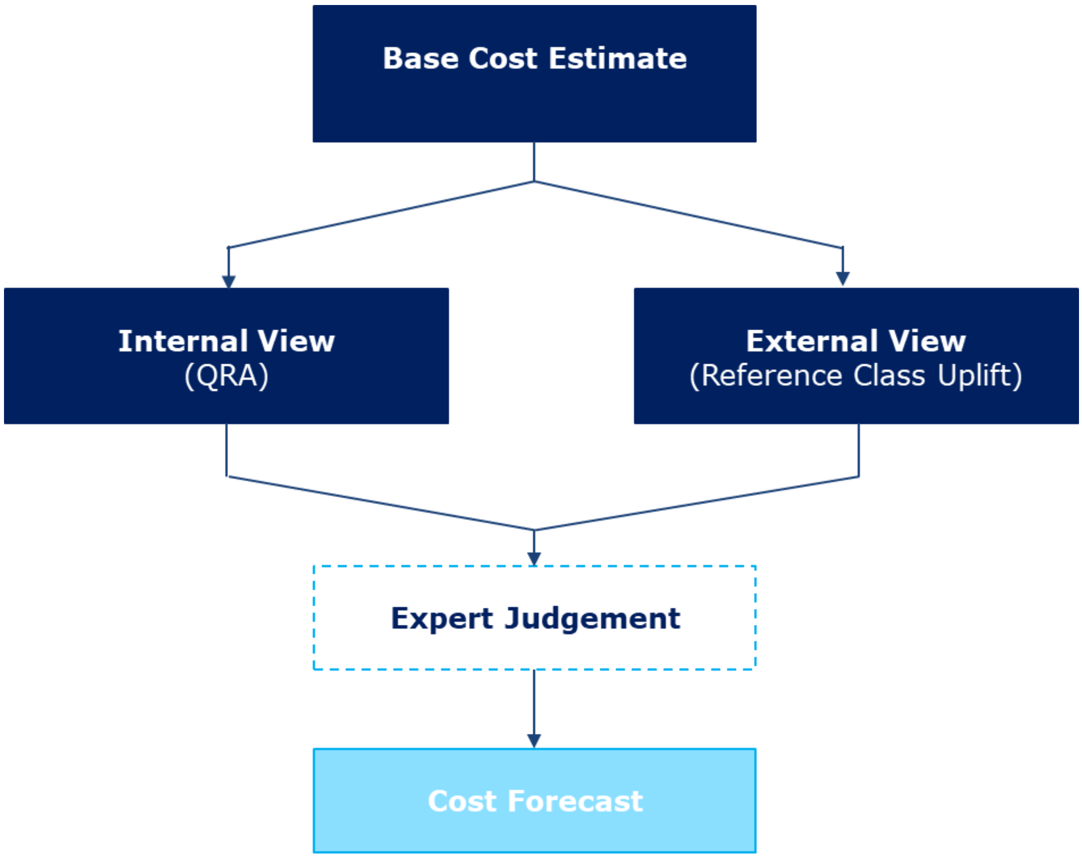


Figure 4 – Graphical Representation of the Cost Forecasting Process

10. References

1. New Children's Hospital: Independent review of escalation in costs: 05 April 2019: PricewaterhouseCoopers
2. Lessons from transport for the sponsorship of major projects: April 2019: Department for Transport and Infrastructure and Projects Authority
3. Cost overruns in transport infrastructure: October 2016: Grattan Institute, Australia
4. Improving Infrastructure Delivery: Project Initiation Route Map, Risk Management Module: June 2016: Infrastructure and Project Authority
5. Reference Class Forecast, Project Report: February 2019: Oxford Global Projects

11. Appendix A – Tier-1 reference classes for cost uplifts at Outline Business Case stage

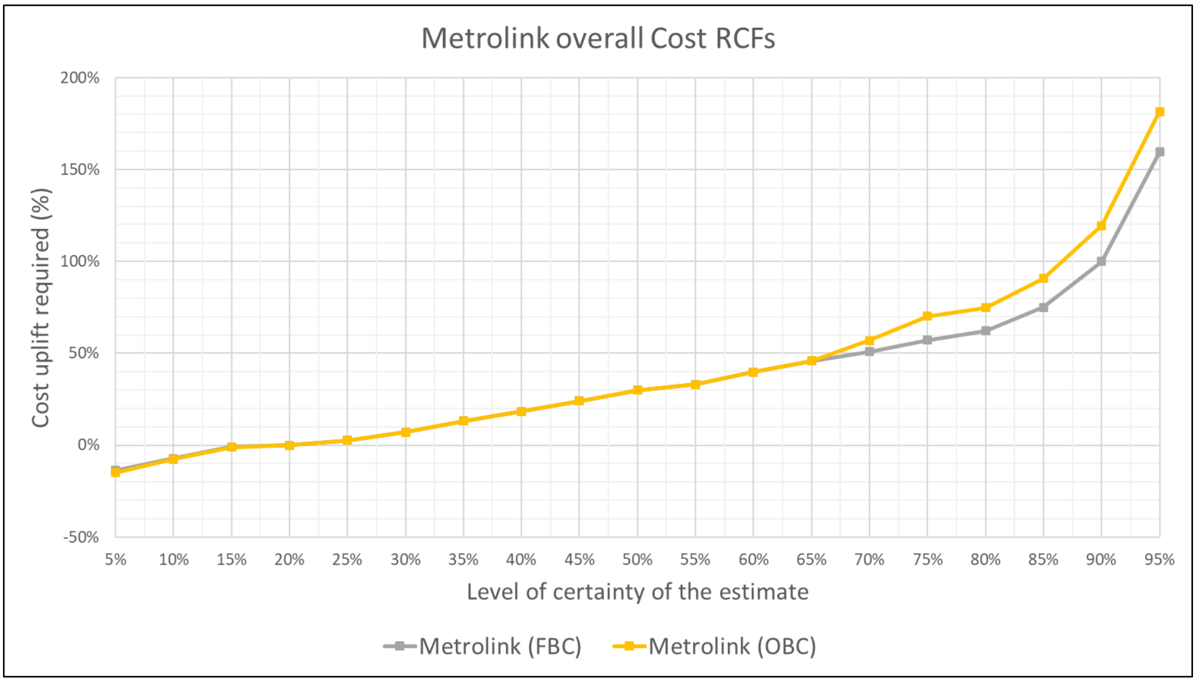
The following table provide the key uplifts for P30, P50, P80 and P90 for the cost and schedule uplifts at the outline business case stage.

Percentile (P-value)	70% acceptable chance of cost overrun (P30)	50% acceptable chance of cost overrun (P50)	20% acceptable chance of cost overrun (P80)	10% acceptable chance of cost overrun (P90)
Metro Overall (Metros & Tunnel)	7%	30%	62%	100%
Tunnels	7%	25%	85%	126%
Stations	2%	14%	107%	220%
Bridges	-1%	12%	62%	105%
Buildings	1%	13%	101%	219%
Urban Rail	13%	38%	77%	104%
Electrification	-1%	0%	32%	43%
Signalling/ Systems	-12%	0%	60%	194%
Rolling Stock	21%	30%	81%	103%
Planning and Design	-37%	2%	67%	126%
Preliminaries	4%	18%	76%	116%
Advance works	-69%	-56%	16%	131%
Utility diversions	1%	8%	58%	71%
Archaeology	-75%	-48%	-6%	0%
IT Systems	-12%	0%	60%	194%
Partner	20%	25%	49%	59%
Construction supervision	-40%	-14%	71%	151%
Construction	3%	16%	72%	102%
Land & Property	-29%	0%	62%	133%

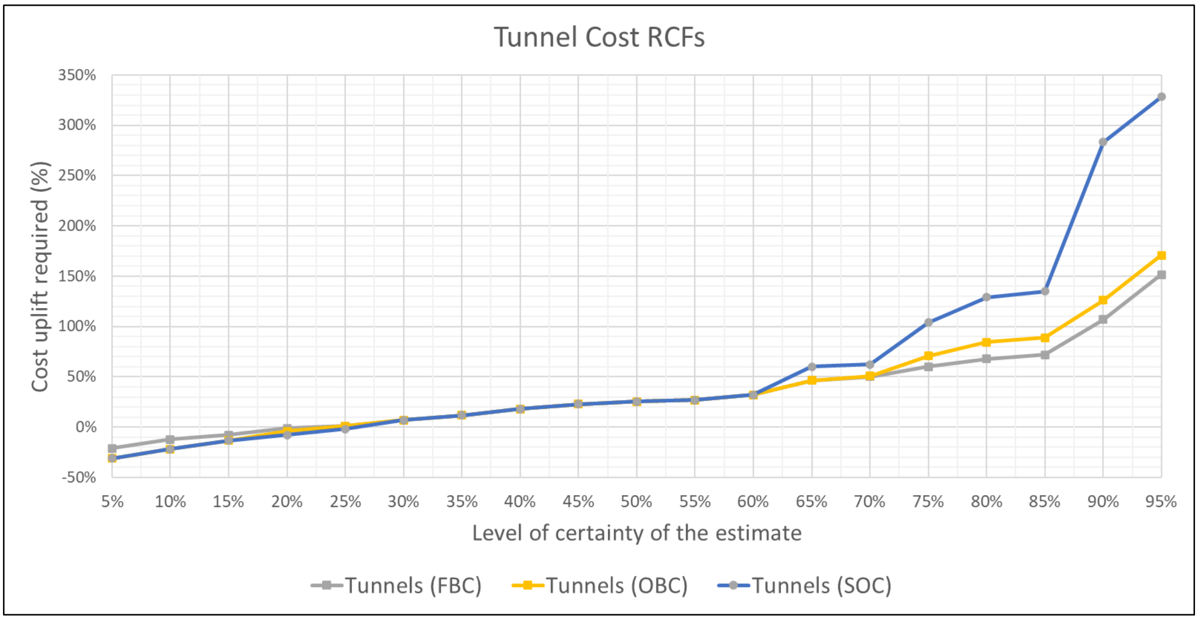
Table 6 – Project Appraisal

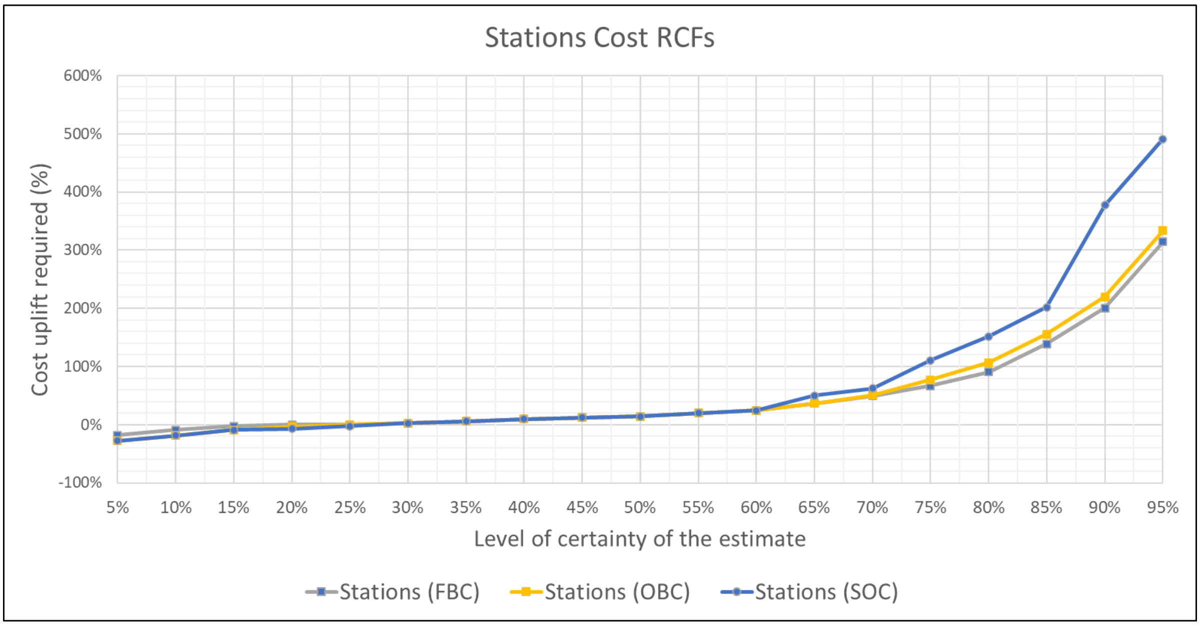
The graphs shown below show the reference class curves which have been developed by Oxford Global Projects to support the development of the Reference Class Forecast for the MetroLink Project. The graphs below have been broken down into the pre-agreed individual asset classes in accordance with table 6 above.

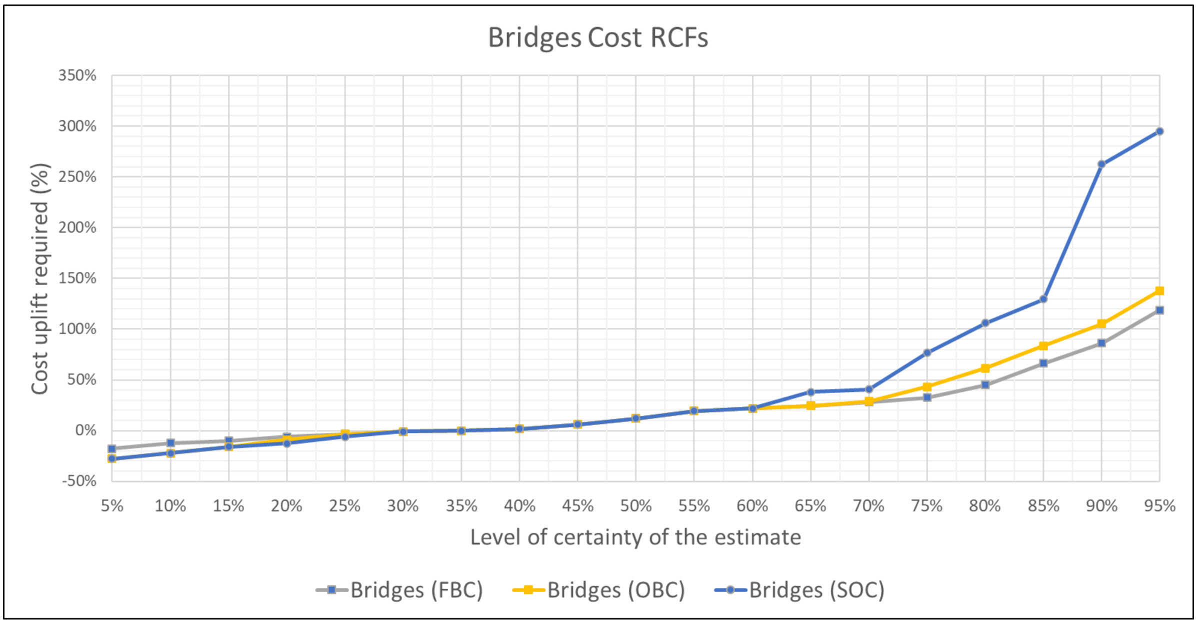
General Curve

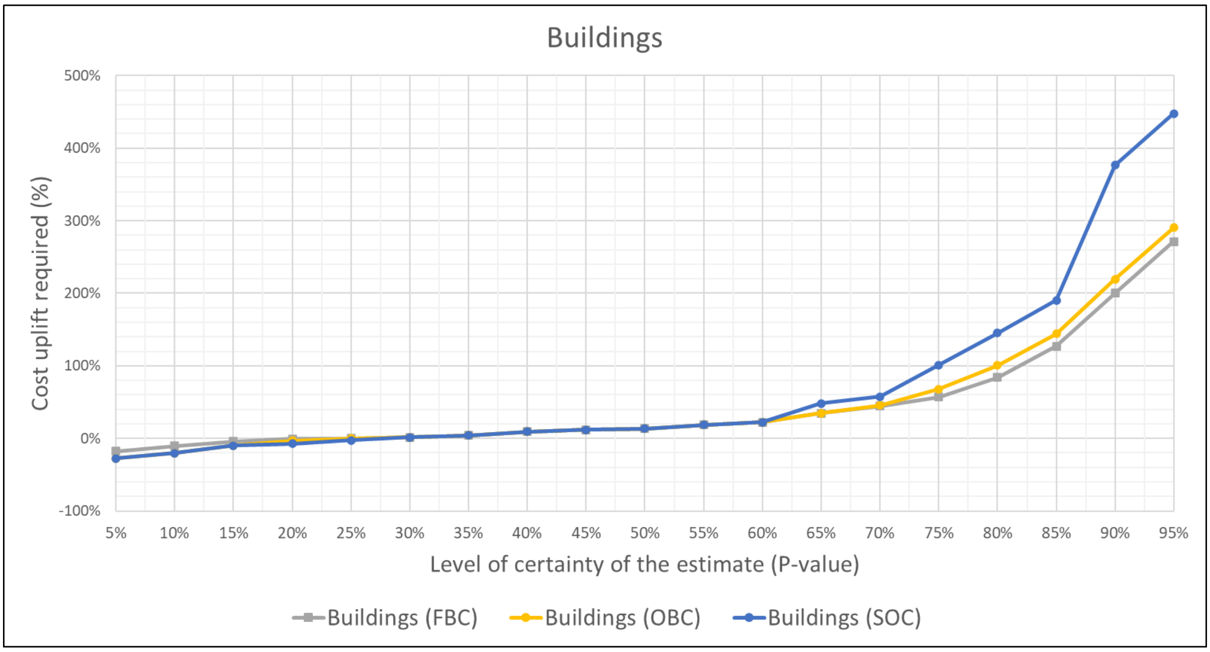


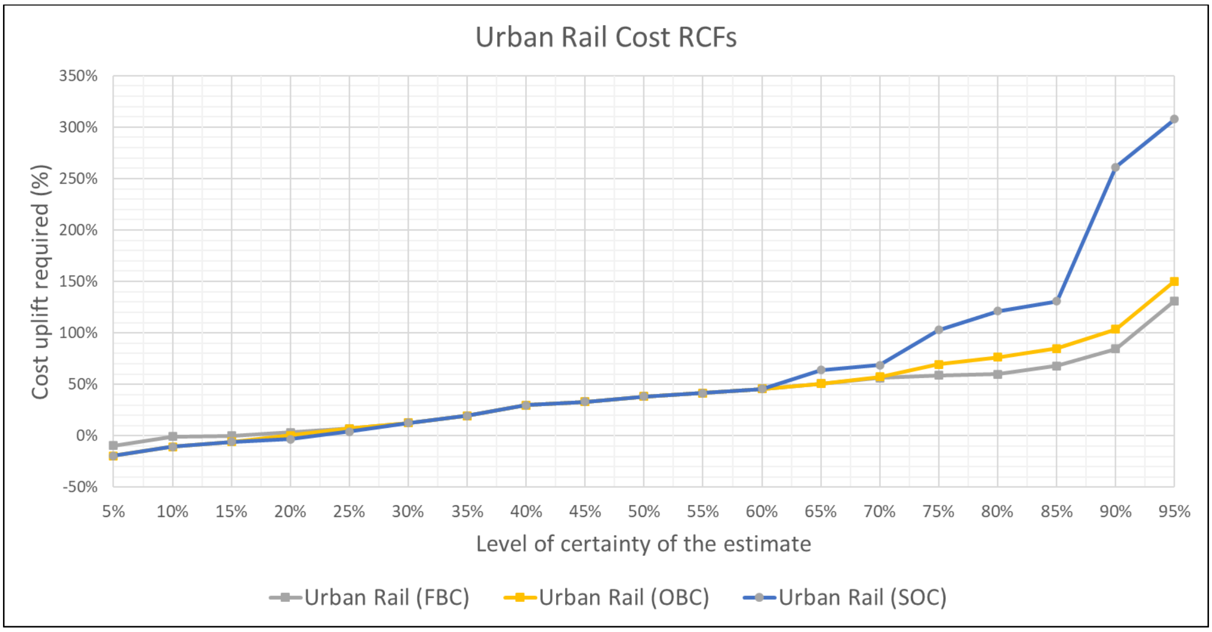
Individual Asset Class Curves

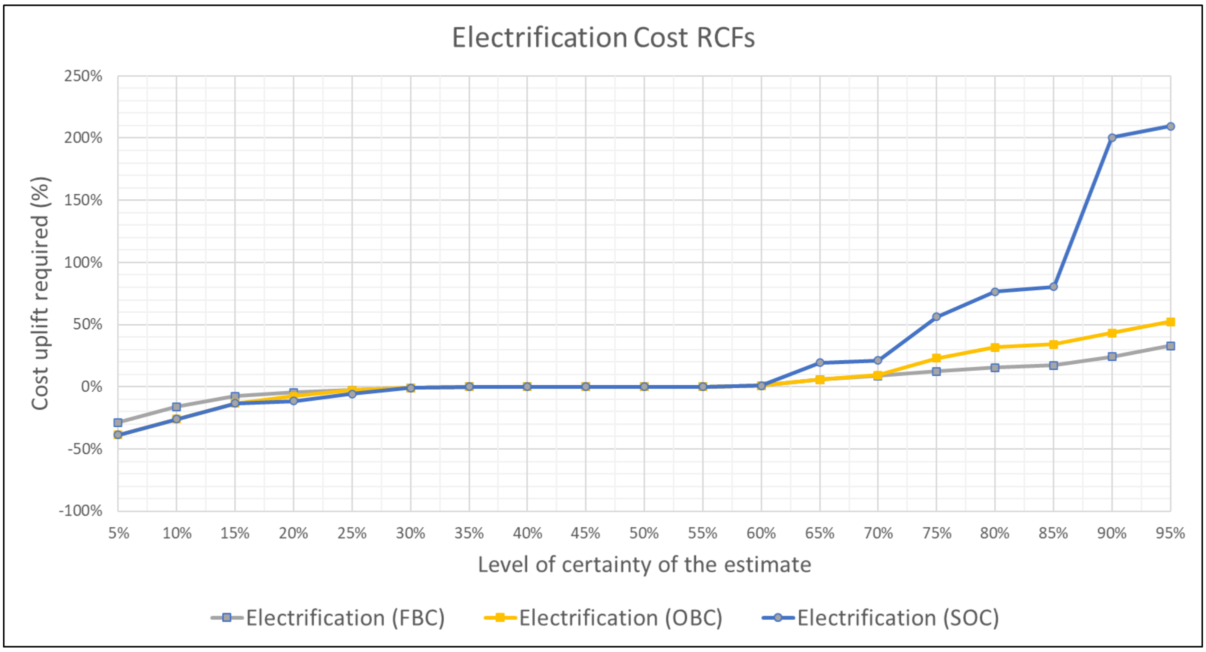


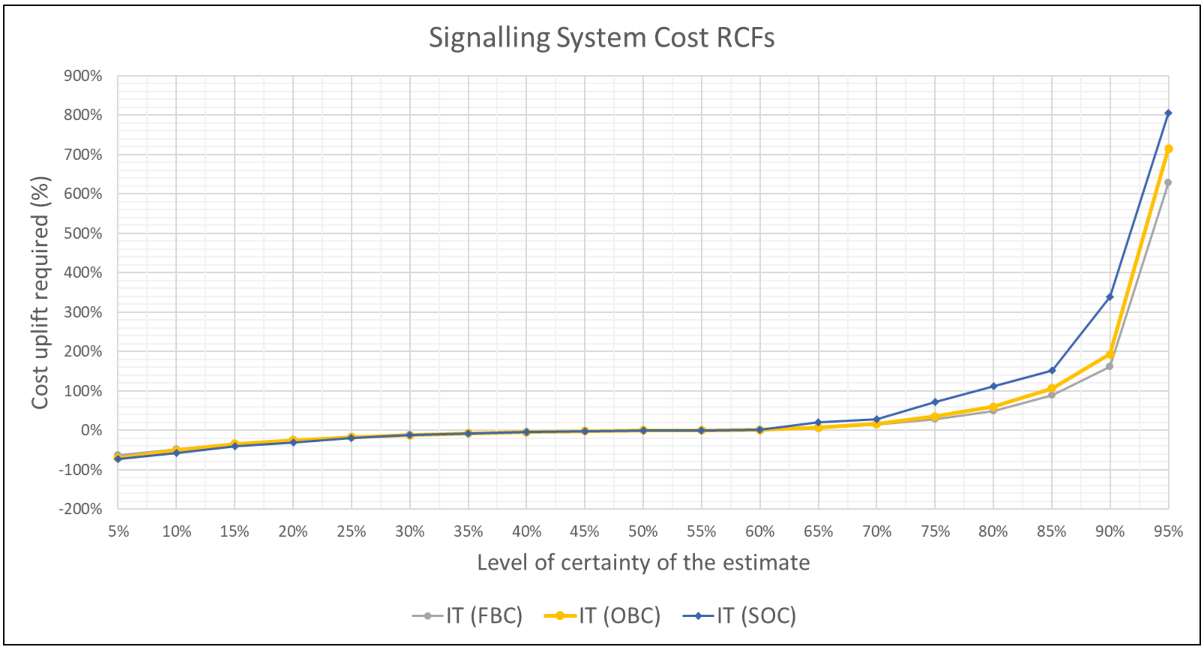

Stations Cost RCFs
600%
500%
400%
300%
200%
100%
0%
-100%
Cost uplift required (%)
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
Level of certainty of the estimate
Stations (FBC)
Stations (OBC)
Stations (SOC)

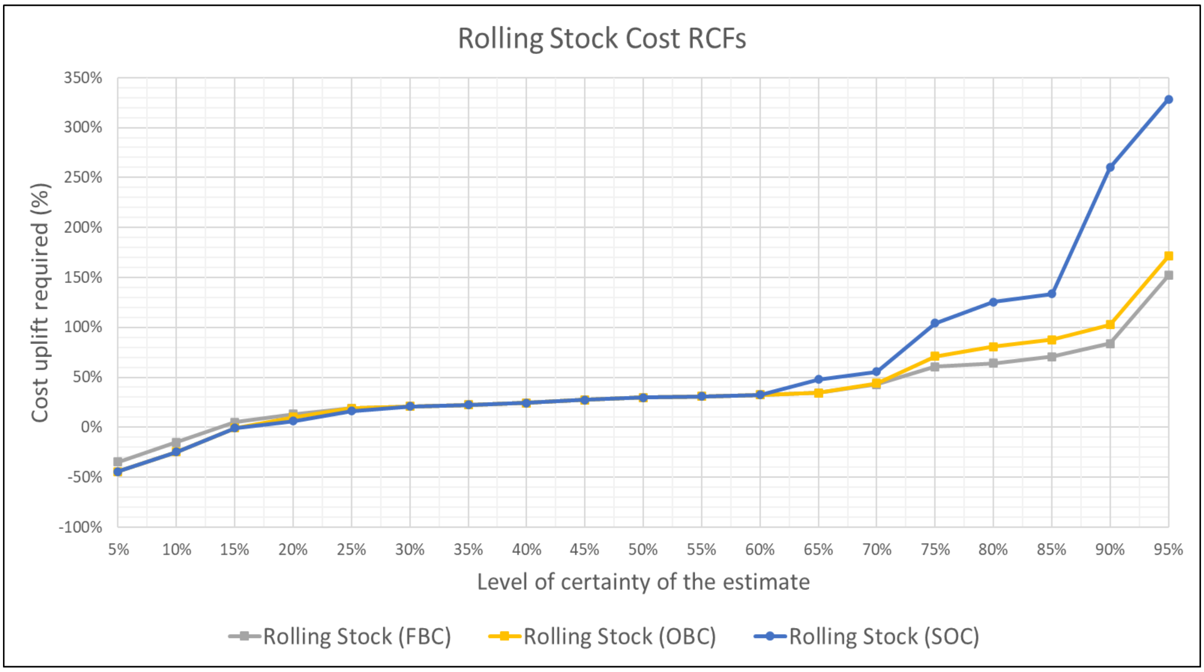

Bridges Cost RCFs
350%
300%
250%
200%
150%
100%
50%
0%
-50%
Cost uplift required (%)
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
Level of certainty of the estimate
Bridges (FBC)
Bridges (OBC)
Bridges (SOC)

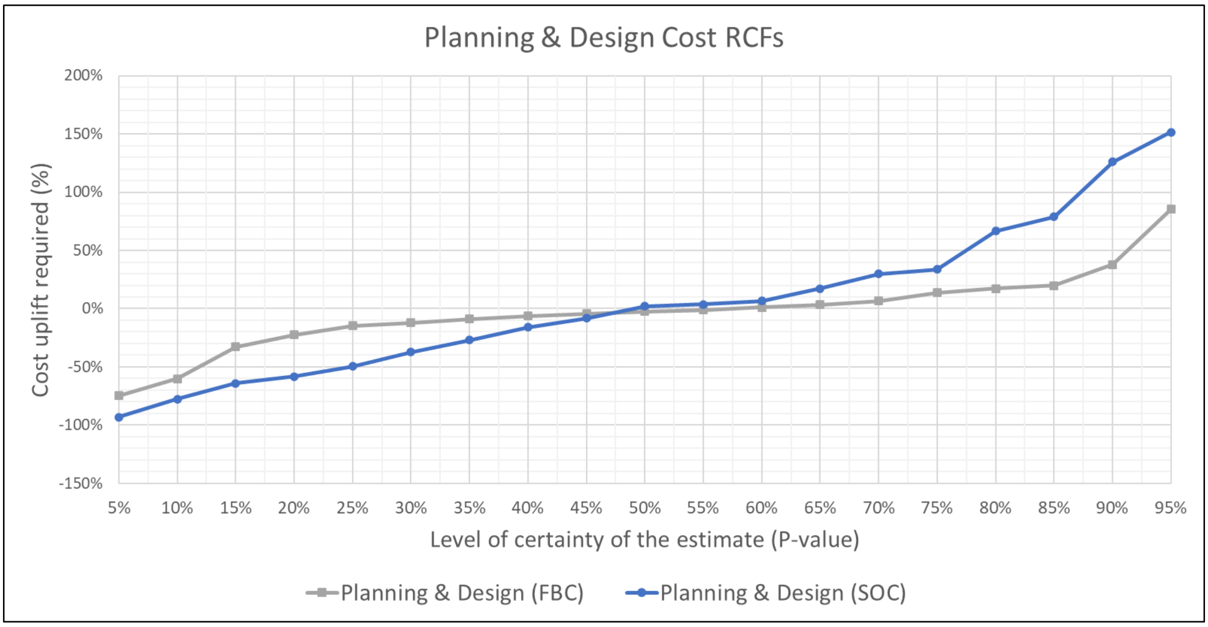

Buildings
500%
400%
300%
200%
100%
0%
-100%
Cost uplift required (%)
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
Level of certainty of the estimate (P-value)
Buildings (FBC)
Buildings (OBC)
Buildings (SOC)

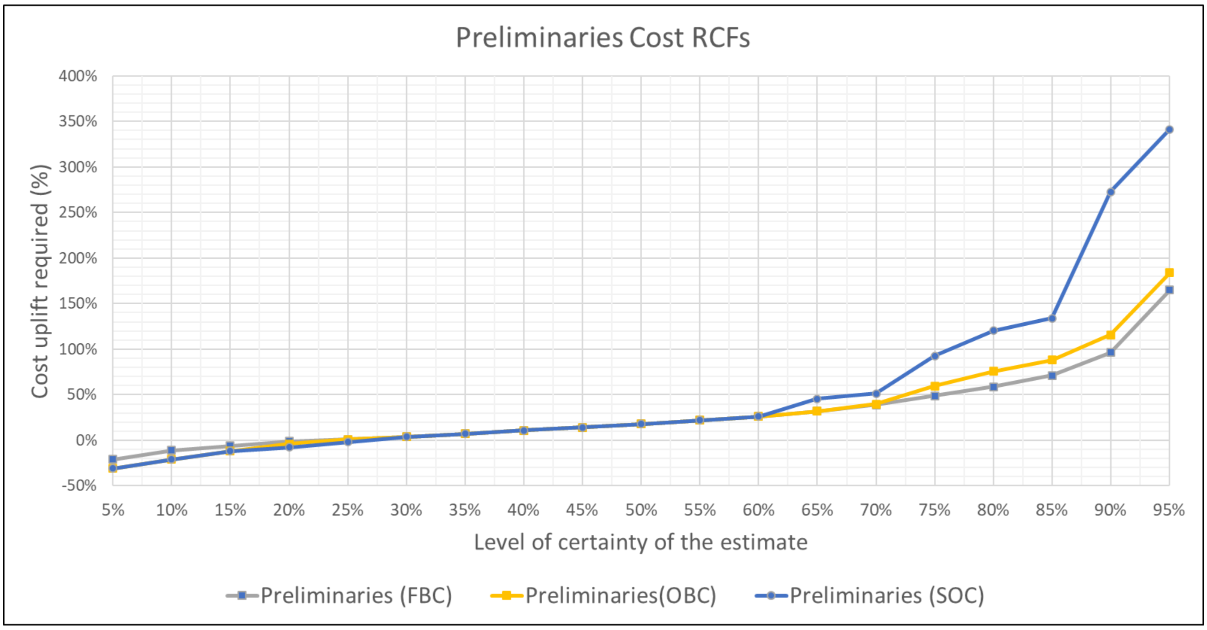

Urban Rail Cost RCFs
350%
300%
250%
200%
150%
100%
50%
0%
-50%
Cost uplift required (%)
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
Level of certainty of the estimate
Urban Rail (FBC)
Urban Rail (OBC)
Urban Rail (SOC)

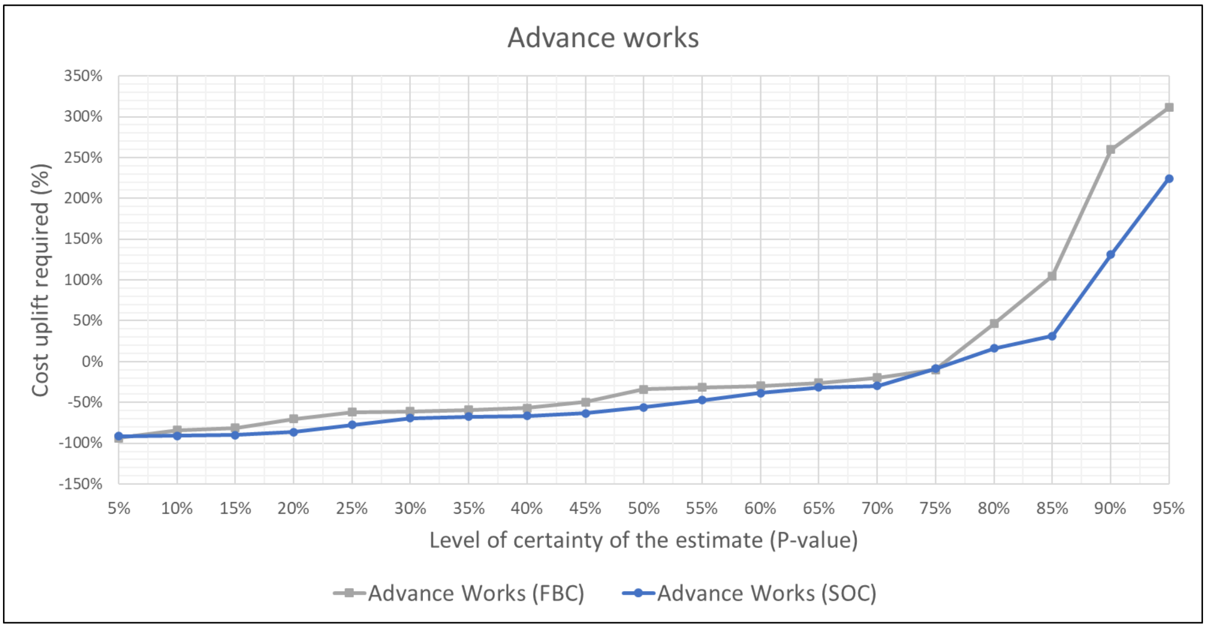

Electrification Cost RCFs
250%
200%
150%
100%
50%
0%
-50%
-100%
Cost uplift required (%)
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
Level of certainty of the estimate
Electrification (FBC)
Electrification (OBC)
Electrification (SOC)

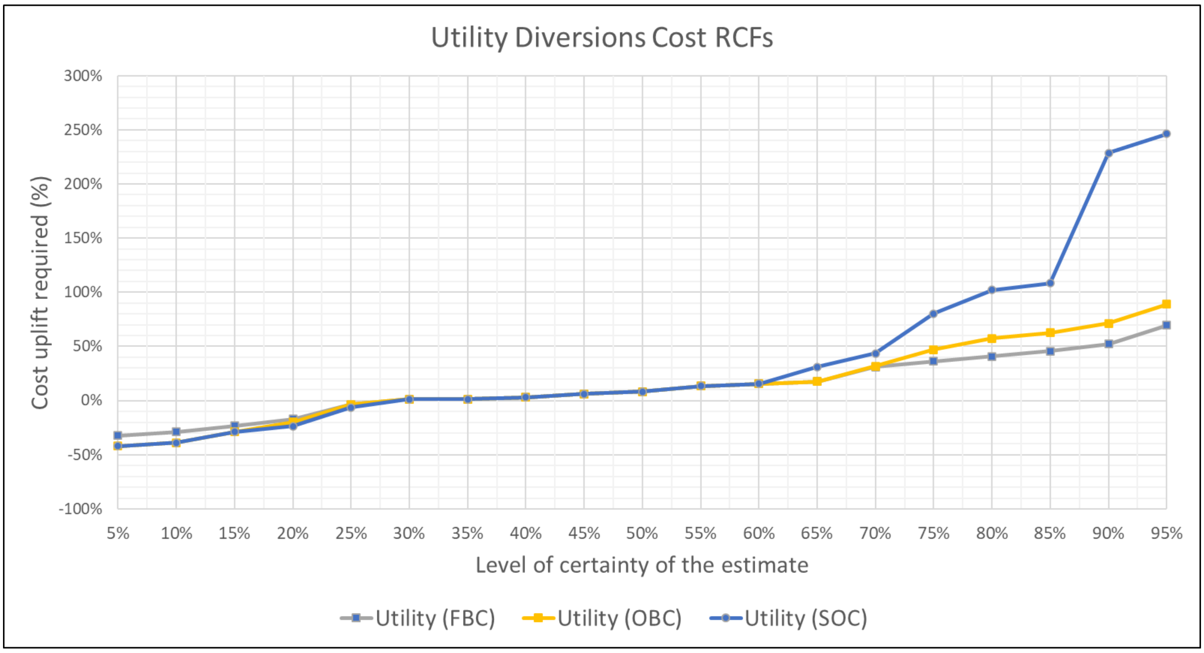

Signalling System Cost RCFs
900%
800%
700%
600%
500%
400%
300%
200%
100%
0%
-100%
-200%
Cost uplift required (%)
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
Level of certainty of the estimate
IT (FBC)
IT (OBC)
IT (SOC)

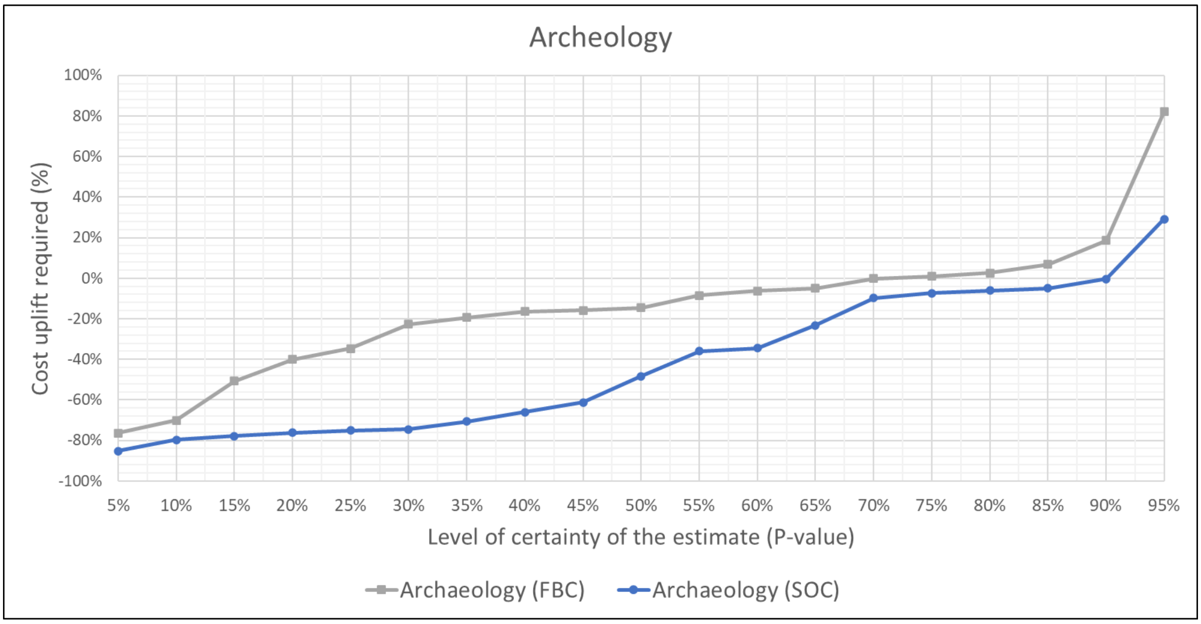

Rolling Stock Cost RCFs
Cost uplift required (%)
350%
300%
250%
200%
150%
100%
50%
0%
-50%
-100%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate
Rolling Stock (FBC)
Rolling Stock (OBC)
Rolling Stock (SOC)

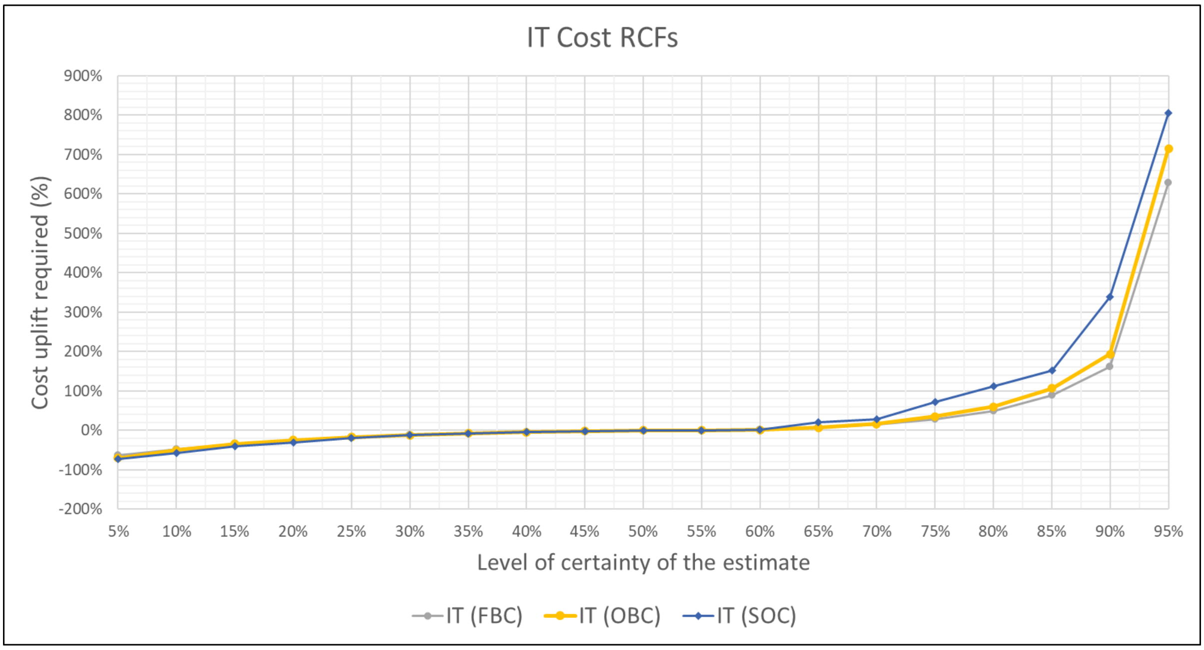

Planning & Design Cost RCFs
Cost uplift required (%)
200%
150%
100%
50%
0%
-50%
-100%
-150%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Planning & Design (FBC)
Planning & Design (SOC)

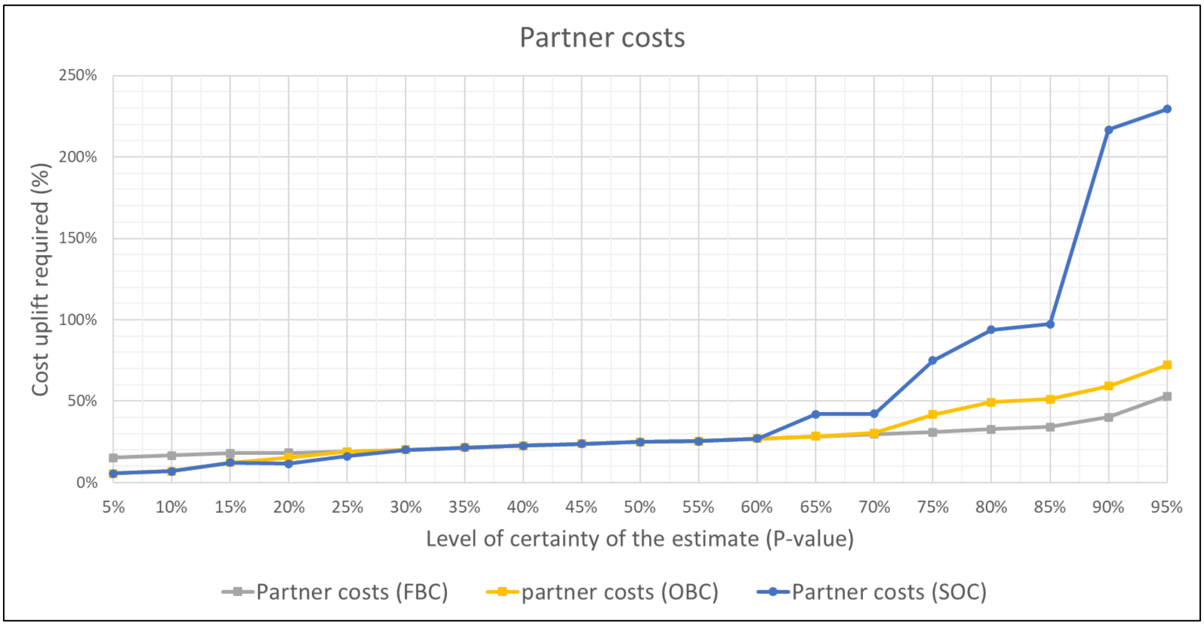

Preliminaries Cost RCFs
Cost uplift required (%)
400%
350%
300%
250%
200%
150%
100%
50%
0%
-50%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate
Preliminaries (FBC)
Preliminaries(OBC)
Preliminaries (SOC)

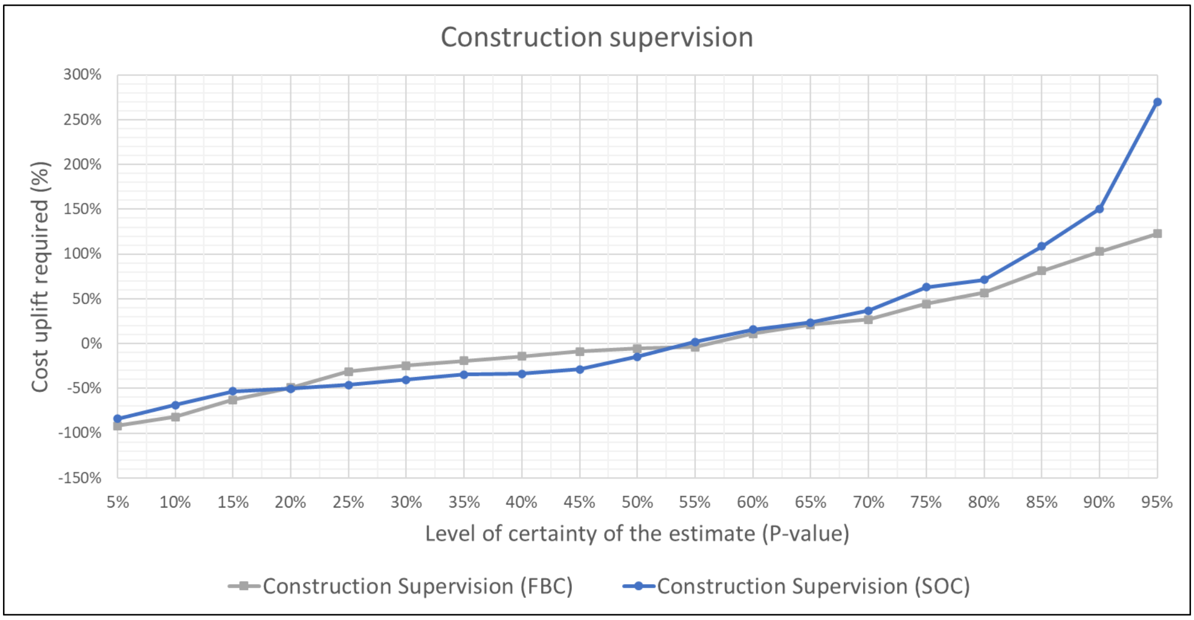

Advance works
Cost uplift required (%)
350%
300%
250%
200%
150%
100%
50%
0%
-50%
-100%
-150%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Advance Works (FBC)
Advance Works (SOC)

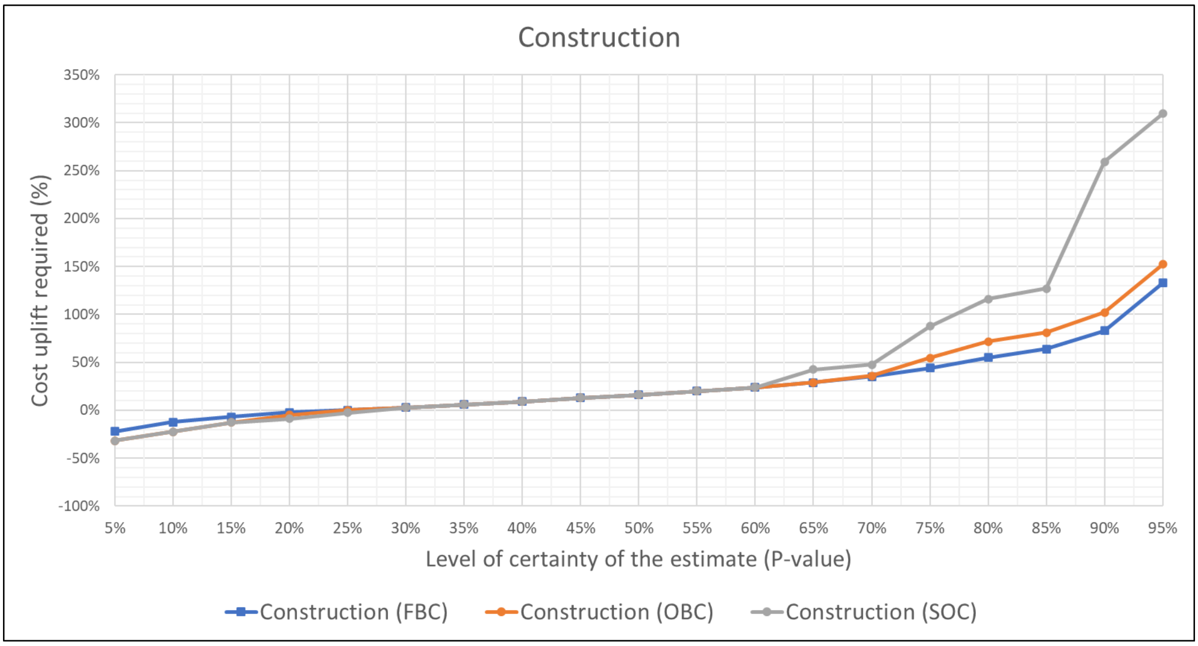

Utility Diversions Cost RCFs
Cost uplift required (%)
300%
250%
200%
150%
100%
50%
0%
-50%
-100%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate
Utility (FBC)
Utility (OBC)
Utility (SOC)

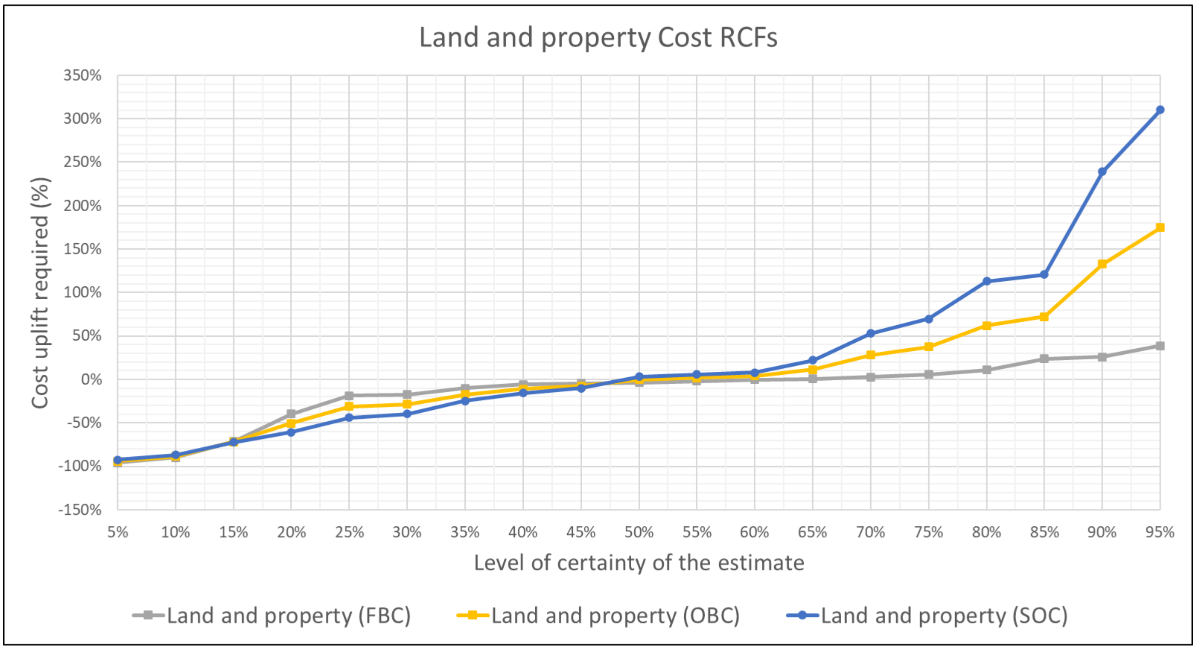

Archeology
Cost uplift required (%)
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Archaeology (FBC)
Archaeology (SOC)


IT Cost RCFs
Cost uplift required (%)
900%
800%
700%
600%
500%
400%
300%
200%
100%
0%
-100%
-200%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate
IT (FBC)
IT (OBC)
IT (SOC)


Partner costs
Cost uplift required (%)
250%
200%
150%
100%
50%
0%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Partner costs (FBC)
partner costs (OBC)
Partner costs (SOC)


Construction supervision
300%
250%
200%
150%
100%
50%
0%
-50%
-100%
-150%
Cost uplift required (%)
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
Level of certainty of the estimate (P-value)
Construction Supervision (FBC)
Construction Supervision (SOC)


Construction
350%
300%
250%
200%
150%
100%
50%
0%
-50%
-100%
Cost uplift required (%)
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
Level of certainty of the estimate (P-value)
Construction (FBC)
Construction (OBC)
Construction (SOC)


Land and property Cost RCFs
350%
300%
250%
200%
150%
100%
50%
0%
-50%
-100%
-150%
Cost uplift required (%)
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
Level of certainty of the estimate
Land and property (FBC)
Land and property (OBC)
Land and property (SOC)

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