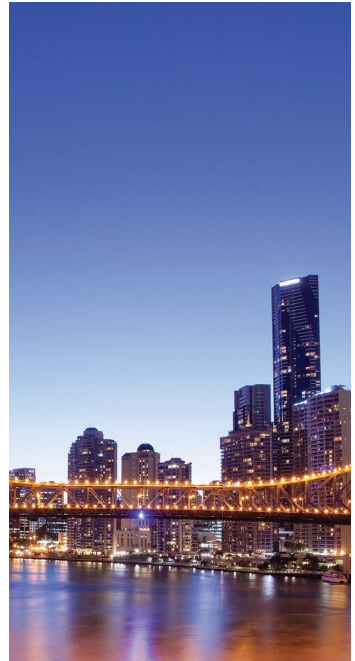




ISP Transmission Cost Database

7 May 2021

Contents

1.	Executive summary	4
2.	Introduction	5
2.1	Context	5
2.2	AEMO objective	6
2.3	Scope of work	6
2.4	Intended use of the TCD	6
2.5	Limitations	7
3.	Approach	8
3.1	Process schematic	8
3.2	Planned timeline	8
3.3	Opening meeting	9
3.4	Stakeholder engagements	9
3.5	Functional specification	9
3.6	Data request template	10
3.7	Establishing the basis of cost estimate	10
3.8	Benchmarking	10
3.9	Qualification and application of TCD estimates	10
3.10	Reporting	10
4.	Stakeholder engagements	11
4.1	Position paper and data request template	11
4.2	Webinar 1	11
4.3	Webinar 2	11
4.4	Webinar 3	12
5.	Treatment of risk	12
5.1	Risk determination in cost estimate	12
5.2	Adopted approach for TCD	13
6.	Functional specification	13
6.1	TCD organisation	14
6.2	Cost estimation organisation	15
6.3	User input organisation	16

6.4	Building block unit rates organisation	16
6.5	Project attribute factors organisation	17
6.6	Known risk factors organisation	18
6.7	Unknown risk factors organisation	19
6.8	Indirect cost factors organisation	19
6.9	Output display organisation	20
7.	Data request template	22
8.	Basis of cost estimate.....	23
8.1	Building blocks.....	23
8.2	Project attributes.....	24
8.3	Known risks	25
8.4	Unknown risks	26
8.5	Indirect costs	31
9.	Benchmarking	31
9.1	Calibration.....	31
9.2	Comparative estimate.....	32
10.	Qualification and application of TCD estimates	33
11.	Future development	35

Appendices

Appendix A	Abbreviation	38
Appendix B	Glossary	40
Appendix C	User Manual.....	42
Appendix D	Custodian Manual (Confidential and for AEMO only).....	57
Appendix E	Blank data request templates.....	71
Appendix F	Comparative estimate results (Confidential and for AEMO only).....	73
Appendix G	Functional Specification.....	78

This report is subject to, and must be read in conjunction with, the limitations set out in section 2.5 and the assumptions and qualifications contained throughout the report.

1. Executive summary

GHD has developed the Transmission Cost Database (TCD) for the Australian Energy Market Operator (AEMO) to address stakeholder recommendations relating to the accuracy and transparency of transmission costs within the Integrated System Plan (ISP). This report documents the development of the TCD which generates early stage cost estimates for electricity transmission network infrastructure major projects.

The TCD is intended to be used by the AEMO to estimate the cost of candidate future ISP projects at early stages of development, and to cross-check Transmission Network Service Providers (TNSP) estimates of 'Actionable' and 'Preparatory Activity' projects, which will be more advanced. It is not intended to be used for detailed estimation of more advanced projects, which require greater design and project definition. The TCD will be publicly available and can be used by industry stakeholders to gain a greater understanding and insight into the development of ISP transmission cost estimates. While stakeholders may use the TCD for planning purposes, AEMO makes no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the database contents or outputs, please refer to the TCD for the full legal disclaimer.

The TCD generates Class 5/4 (early stage) project cost estimates in a deterministic fashion, compiling various cost components that make up the total cost. The TCD does this by assembling varieties of required asset building blocks from a comprehensive database to match the given scope of work and adjusts their costs to reflect project specific attributes and risk exposures based on user inputs. The TCD has been developed in an Excel platform and consists of the following two separate files:

- Cost & Risk Data workbook – an Excel file containing the complete listing of building block costs, and attribute and risk factors (master file for administrator use)
- Cost estimation tool – an Excel file that allows users to build up a project cost estimate based on the Cost & Risk Data workbook (contains a copy of the Cost & Risk Data workbook and is published for AEMO and stakeholder use).

This report describes the organisation of the TCD, its various components and the data or variable that resides within those components. The report describes the basis of these variables and how they are used to compile project cost estimates driven by user inputs. More importantly, this report focuses on the risk estimation topic and its inclusion in project cost estimates, especially at the early estimate stage.

We have referred to industry recognised Association for the Advancement of Cost Engineering International (AACE) guideline and recommended practice note, and then tailored that guidance to the Australian context by analysing recent examples of cost estimation of major projects in the National Energy Market (NEM) progressing from early to advanced stage to deduce the accuracy range and risk factors in early stage cost estimates.

We have outlined the nuances and diligence needed to use the TCD as intended given the design of the TCD, the scope of various variables used, and the requirement for unbiased and objective user inputs and selection to produce early stage project cost estimates in this report.

This report also documents various activities that we undertook during the course of the TCD development to incorporate the views of various industry stakeholders, providing documented answers to their questions, and to test and calibrate the developed TCD by benchmarking it against industry cost estimates.

Finally, this report includes a user manual targeted to industry professionals to increase user friendliness of this cost estimating tool. A custodian manual is also included, targeted to AEMO staff for the purpose of housekeeping, regular maintenance and administration of the TCD.

2. Introduction

2.1 Context

Various stakeholders within the NEM have requested increased transparency in transmission costs used in the ISP. They have also observed underestimation of major projects within the ISP and Regulatory Investment Test for Transmission (RIT-T) process as the project matures through its project development stages. A review¹ commissioned by the AEMO in 2020 has attributed the reason for cost underestimation in the early stages of project development to the following likely factors:

- Lack of large-scale transmission construction projects since Basslink in 2005
- Lack of detail on brownfield work scope required
- Changes in Australian Standards
- Risk contingencies – for large projects unable to use portfolio effect across Business as Usual (BAU) projects
- Internal costs – limited understanding of costs of managing large projects
- Property – large team required to undertake acquisition as well as stakeholder engagement to ensure project is supported
- Time pressures – externally imposed, may not reflect actual time to deliver project, resulting in increased costs to accelerate
- Little incentive to undertake detailed work at an early stage
- Biodiversity – greenfield projects impact threatened species with high offset values, not able to be fully understood until significant work is undertaken
- TNSP organisations current inexperience to negotiate, procure and manage major, complex contracts
- Negative community sentiment forcing late alignment changes
- Compulsory acquisitions – number or timing
- Pressure on labour rates
- Road improvements / access tracks – not considered in early stages
- Interface risk – road, rail, utility interfaces not understood.

This review proposed and outlined a cost estimating framework. The review provided an overview of the proposed scope of work for estimating costs, the target accuracy of cost forecasts at each stage of the regulatory process, as the plan progresses from candidate future ISP projects through to RIT-T process and to the Contingent Project Application (CPA) submission. This review also recommended the development of a TCD to support more accurate estimation of project costs in the early stages of development.

Under the outlined cost estimating framework, the level of target cost certainty increases at each stage as additional planning, investigations and design works are completed.

¹ https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2021/Transmission-Cost-Database-Phase-1-Report.pdf

In late 2020, AEMO engaged GHD Advisory to deliver this recommendation.

2.2 AEMO objective

The aims of this engagement included:

- Improve the accuracy of the transmission cost estimates used in the ISP
- Increase the detail of cost estimates available to AEMO and to stakeholders
- Provide clarity on the work required and level of accuracy expected at each stage of the regulatory approvals process
- Increase stakeholder confidence in transmission costs used in future ISPs.

AEMO understands that accurate cost estimation is pivotal to the assessment of transmission projects in the ISP. AEMO wants to use the newly developed TCD primarily to estimate the cost of future ISP projects.

The initial version of the TCD will be made publicly available and will be used for the 2022 ISP.

The TCD will be owned by AEMO and will be improved and refined as new cost information becomes available in the future.

2.3 Scope of work

Our scope of work included:

- Update of AEMO's existing inhouse Price Book, an Excel spreadsheet, containing estimated rates for unitised asset class or rates for asset group for unitised quantity asset. These are used as building block ingredients for bottom-up cost estimation; and also add new building blocks unit rate information specified by AEMO
- Define and develop the structure to modify the cost estimate from the building block approach to incorporate various adjustment factors such as project specific attributes, known risks, unknown risks and indirect costs. This scope together with the above is the Cost and Risk Data workbook
- Develop a cost estimation tool using the VBA programming language and macro codes in an Excel environment to automate the interfacing of various components of Cost and Risk Data workbook driven by user inputs to produce cost estimate for given scope of project work. This cost estimation tool together with Cost and Risk Data workbook is the TCD and produces bottom up estimates based on early stage project scope (i.e. Class 5 and Class 4 estimates).

2.4 Intended use of the TCD

ISP modelling requires cost inputs for projects at all stages of development prior to the CPA stage. As described by the AACE cost estimate classification, the accuracy of the cost estimate increases as the project development advances with the level of design detail to maturity.

AEMO intend to use the TCD to produce high level (Class 5/4) cost estimates only. The TCD will be used to estimate the cost of candidate future ISP projects and to cross-check TNSP estimates of 'Actionable' and 'Future with Preparatory Activities' projects. This is illustrated in the following Table.

Table 1 Intended use of the TCD

Stage	Future ISP projects	Future ISP projects with preparatory activities	Project Assessment Draft Report (PADR) in development or completed	Project Assessment Conclusions Report (PACR) completed	Contingent Project Application (CPA) and ISP feedback Loop
Example Projects	Network expansion options and candidate REZs in early stages	QNI Medium and Large, CQSQ, New England REZ etc	HumeLink, Marinus Link, Central-West Orana, VNI West		PEC, VNI Minor (NSW works)
Price certainty*	Class 5/4	Class 4/3	Class 4/3	Class 4/3	Class 3/2
Source of ISP Estimate	TCD	TNSP	TNSP	TNSP	Not required for ISP

*Class levels shown here reflect AEMO's understanding at the time of submission of this report by GHD. Discussions on estimate accuracy are ongoing and will be addressed further at future webinar(s).

We envisage that apart from AEMO, the TCD will be used by energy industry individuals, entities and stakeholders, with knowledge of transmission network capital projects and assets.

2.5 Limitations

This report has been prepared by GHD for AEMO and may only be used and relied on by AEMO for the purpose agreed between GHD and AEMO as set out in section 2.3 of this report.

GHD otherwise disclaims responsibility to any person other than AEMO arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by AEMO, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

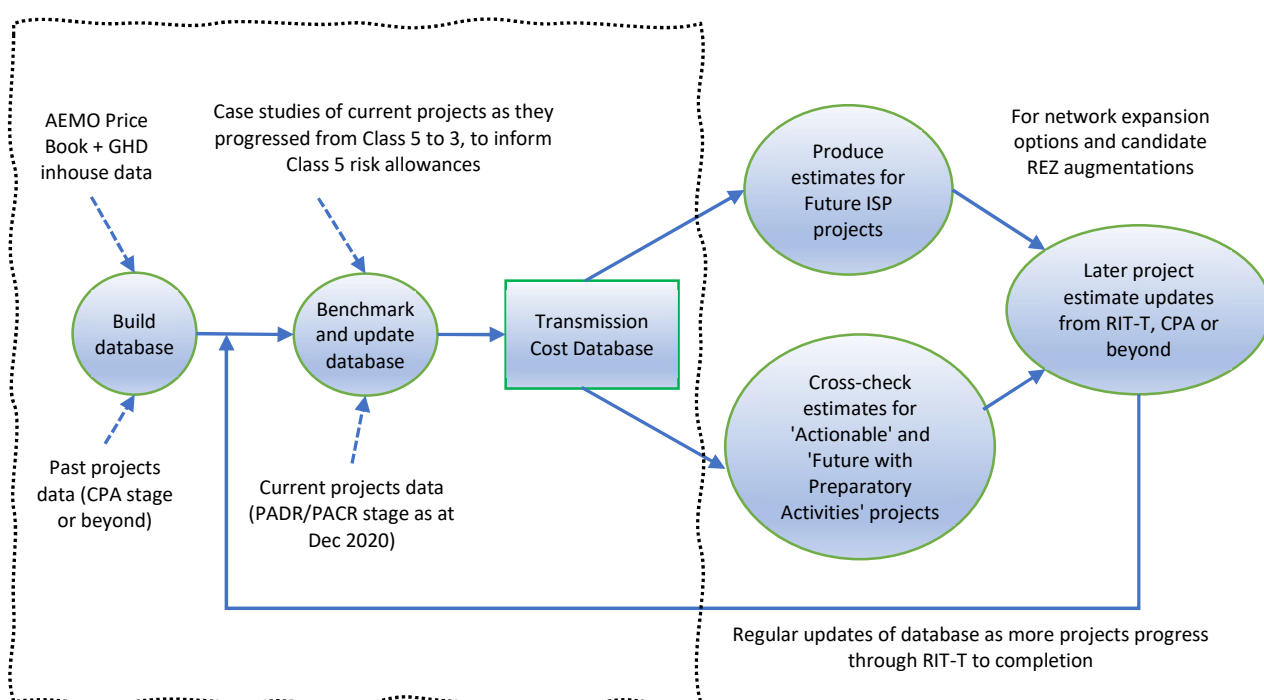
3. Approach

The approach we undertook to deliver this assignment is summarised below with the main areas of work briefly described in the following sub-sections.

3.1 Process schematic

The following figure illustrates the process of developing the cost estimating database and the intended use and maintenance of the database in the future.

Figure 1 Process schematic

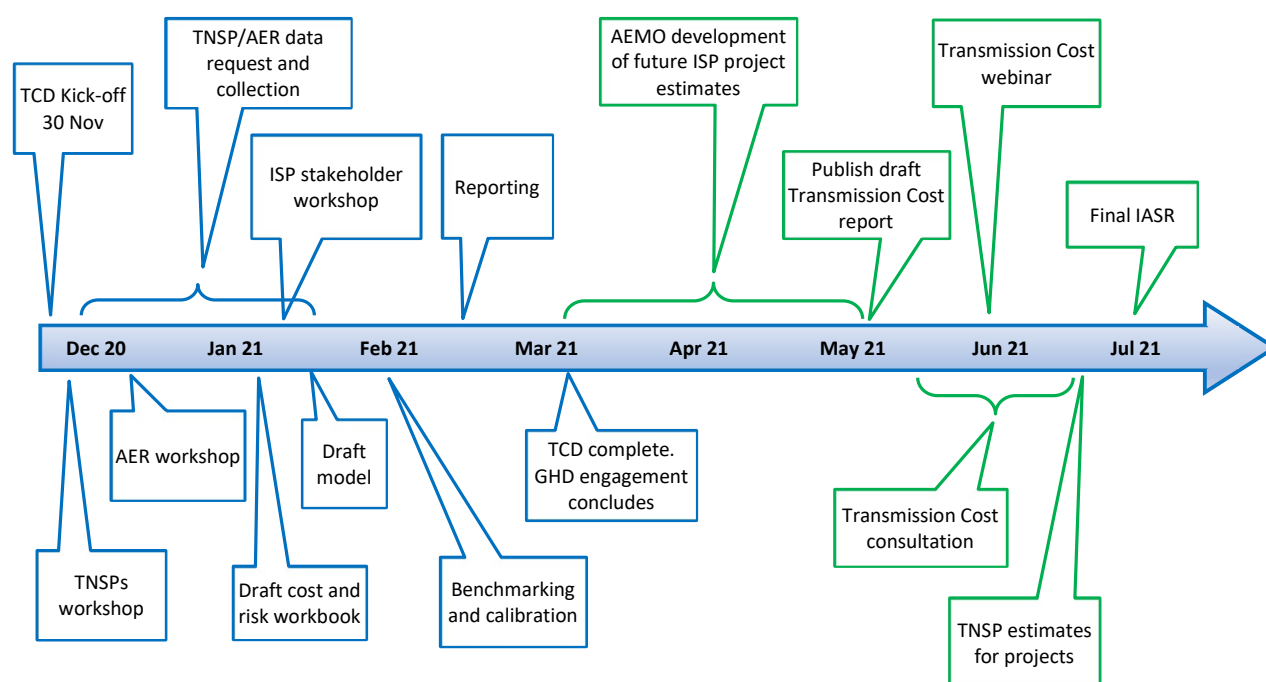


The dotted area in the above figure illustrates the cost estimating database development activities and is the scope of GHD engagement with AEMO.

3.2 Planned timeline

The following figure shows the planned timeline for developing the transmission cost inputs highlighting the key milestones in lead up to the publication of the Input, Assumption and Scenario Report (IASR) for the 2022 ISP.

Figure 2 Planned timeline



The initial milestones showing various activities culminating in the development of the TCD in March 2021 constitutes GHD's scope of work.

3.3 Opening meeting

An opening meeting between AEMO and GHD project teams took place on 30 November 2020 to start the engagement of GHD's scope of work. This meeting was used by all team members from both entities to introduce themselves and their respective role and involvement in the scope of work.

The logistic and resourcing of various activities along with the standard project administration requirements and reporting were discussed and noted.

3.4 Stakeholder engagements

During the initial phase of this engagement, we organised three webinars in order to provide the various groups of stakeholders an overview of our approach to this engagement, focusing on the treatment of risk, and an opportunity to comment and ask questions on the proposed approach. All three webinars included a Q&A session. This step is described in more detail in section 4.

3.5 Functional specification

At the beginning of this engagement, we drafted a functional specification document detailing our 'road map' on the design of the Cost and Risk Data workbook and its various components, and the interaction between them driven by the user inputs to deliver cost estimate outputs. This is described in more detail in section 5.

3.6 Data request template

During the initial phase of this engagement, we drafted a data request template to collect the project cost information from TNSPs and the AER in a consistent fashion. We identified a selection of projects with an intention to obtain various versions of its cost estimate as it progressed through to various investment or regulatory decision gates representing the advancing estimate maturity from Class 5 to Class 3.

Cost estimate information collected in such a fashion were used for TCD benchmarking purpose. This is described in more detail in section 7.

3.7 Establishing the basis of cost estimate

We referred to AEMO's specification for various components and variables of the TCD (i.e. building blocks, attribute factors, risk factors and indirect costs) required to build-up the project cost estimate.

We also referred to the AACE guideline and recommended practice notes on treatment of risk and its incorporation within a project cost estimate at different stages of project development and the corresponding accuracy range. This included drafting the library of the building block unit cost estimates, project attributes, known risk, unknown risk and indirect costs meeting all the requirements of AEMO's specification in an Excel environment. This also involved structuring the Cost and Risk Data workbook in a specific fashion to facilitate the development of the cost estimation tool as a part of the TCD development.

A cost estimation tool was developed using the VBA programming language and macro codes in an Excel environment. These algorithms followed the intention established in the Functional Specification document.

The cost estimation tool together with the Cost and Risk Data workbook constitute the TCD. This is described in greater detail in section 8.

3.8 Benchmarking

After collecting the requested benchmarking data, each project was broken down into its individual network elements and scoping details (i.e. types of building block, quantities, application of risk etc.) from each network element was derived. These scoping details were then entered in the TCD for each network element to formulate the overall project cost and compared against the TNSPs' estimate for benchmarking and variable calibration purpose. This is described in more detail in section 9.

3.9 Qualification and application of TCD estimates

We described how the cost estimates generated from the TCD should be qualified and applied as single point estimate and used for the ISP modelling purpose, accounting for the accuracy ranges. This is discussed in more detail in section 10.

3.10 Reporting

The final stage of this engagement involved preparation of this report including the user manual (Appendix C), custodian manual (Appendix D) and our recommendation for future development in section 11.

4. Stakeholder engagements

During the initial phase of this engagement, we organised three webinars in order to provide the following groups of stakeholders an overview of our approach to this engagement, focusing on the treatment of risk, and an opportunity to comment and ask questions on the proposed approach:

- Webinar 1: with all participating TNSPs in the NEM on 9 December 2020
- Webinar 2: with the AER on 15 December 2020
- Webinar 3: with the ISP stakeholders on 20 January 2021.

All three webinars included a Q&A session.

4.1 Position paper and data request template

As part of the activity in the first and second webinars, we prepared a position paper on treatment of risks topic describing our proposed approach in determining and including risks in the project cost estimates. This position paper formed part of the pre-reading material to prepare the first and second webinars attendees for active participation in the session to enrich the process.

We also drafted and issued the data request template in the first and second webinars with an intention of collecting recent project cost estimates from the respective proponents in consistent fashion for the purpose of benchmarking and calibrating the TCD variables. Please see section 7 for more details on data request.

4.2 Webinar 1

The first webinar was attended by all the TNSPs from the NEM. In general, the discussion and feedback were with respect to the:

- Proposed approach was supportive as the TNSPs considered it to be reasonable. The need to maintain the building block in the TCD at a fairly high level was requested given the intended use of the TCD
- Treatment of risks and its inclusion in the cost estimate consisted of detailed queries and comments on various risk factors, its identification, determining the parameters, the need to use consistent risk nomenclature, and the changing nature of cost estimates as it progresses through regulatory approval process
- Data request raised the need to consult with their respective legal team before provision of such data and thereby the impact on timeline. Some TNSP's highlighted the absence of any major augmentation projects in their foreseeable plan and one raised concern for the need to manage the potential perception of cartel behaviour when sharing cost estimate information.

4.3 Webinar 2

The second webinar was attended by the AER. In general, the discussion and feedback were with respect to the:

- Proposed approach raised the challenges in estimating the cost for bespoke projects being addressed with varieties of building blocks and adjustment factors (attributes and risks) while considering the trade-off between granularity vs user friendliness and wider application

- Treatment of risk and its inclusion in the cost estimate consisted of detailed queries and comments on double counting/overlap between various risk factors, being embedded within the building blocks (double counting), the need for transparency, need to show the effect of risk selection, and the need for user guidelines and prompts. The AER also commented that the CPA stage estimate should not have any unknown risks
- Data request raised the need to consult with the respective TNSP to whom the cost estimate belongs and the need to navigate confidentiality issue, thereby impacting the timeline. The AER also highlighted the possibility of two views of the same cost estimate (i.e. TNSP version and their view on it).

4.4 Webinar 3

The third webinar was attended by a range of ISP stakeholders. The agenda of this webinar was to explain the approach taken, focusing on the treatment of risk, and outlining the structure, construction, functionality and the intended usage of the TCD. In general, the questions and feedback were with respect to:

- The proposed approach raised questions regarding the accuracy range and the shifting (increasing) estimates currently experienced by the industry especially as projects progress through various regulatory decision gates; adoption of the AACE guidelines and its recommended practice notes into Australian context; the consideration of non-network solutions outside of the TCD; and the use of benchmarking
- The treatment of risk focused on consistent use of terminologies; use of fixed cost contract to transfer risk; and the transparent allocation of risks to the cost estimate
- TCD and its usage focused on the functionality of the modelling tool to generate cost estimates for new projects using the building block approach; the use of the TCD in the ISP modelling purposes; and future or continual upkeep of the TCD.

The above discussions are captured in the webinar recording which is available for public viewing [here](#). All the questions received during the webinar were responded to during and after the webinar. These responses are documented and published [here](#).

5. Treatment of risk

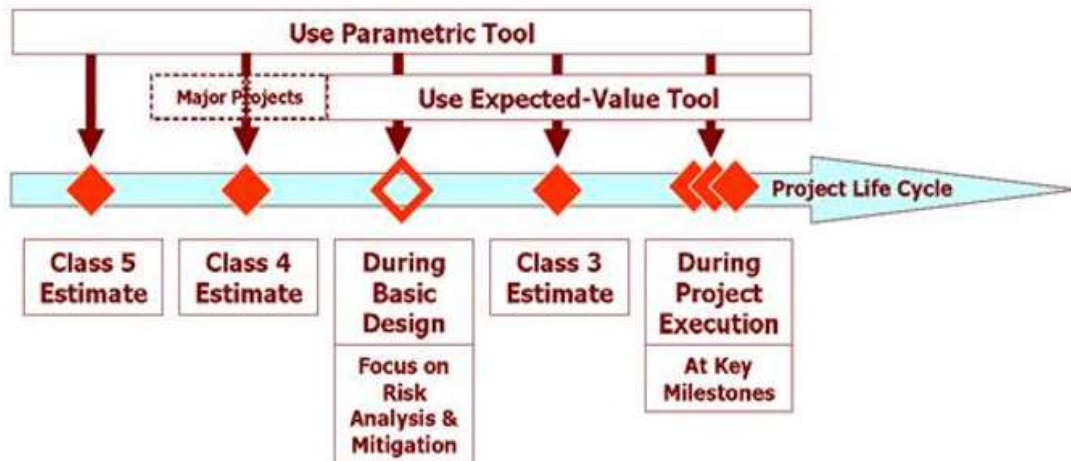
5.1 Risk determination in cost estimate

The AACE defines four approaches to risk assessment and provide guidance on when they should be considered across the estimate phases. The four approaches are:

- Expert judgement
- Parametric modelling using predetermined guidelines with a hybrid of judgement and empirical use of historical norms
- Parametric modelling using more sophisticated empirical models usually derived through regression analysis. This requires a strong historical data set being available
- Simulation analysis (Expected Value Tools):
 - Qualitative risk assessment using range estimating and probabilities to derive an expected value
 - More sophisticated Monte-Carlo based analysis using expertise in stochastic risk processes.

The AACE note RP 42R-08 provides the following diagram that illustrates the use of different tools over the stages of estimate accuracy. The document states that for Class 5/4 estimates, the use of Parametric Tools is appropriate and from Class 3 estimates, Parametric Tools supplemented by Expected Value Tools are appropriate to be used.

Figure 3 Risk determination approach and tools



5.2 Adopted approach for TCD

The more sophisticated form of Parametric Tools using regression analysis is only suitable if there is sufficient historical project data available. For major transmission network infrastructure projects considered in the ISP such as interconnectors and new connections/augmentations to Renewable Energy Zones (REZ), this is not possible due to limited information/recent projects in Australia. Our preferred choice for costs estimates and risk determination for the TCD is parametric modelling using predetermined guidelines with a hybrid of judgement and empirical use of historic norms.

The AACE also notes that at early stages of project estimates (i.e. Class 5/4 estimate) where the project work breakdown structure (i.e. network element) and its scope is poorly defined, the use of a more sophisticated approach is ineffective and meaningless. In other words, tools such as Monte Carlo simulations (to generate P-estimates associated with statistical qualifications such as confidence level, probability distribution functions, standard deviation etc.) are ineffective for Class 5/4 estimates.

We have categorised the project risks into the following two factors:

- Known risks (where risks are identified but the ultimate value of the risk is not known). The basis for this risk is described in Section 8.3
- Unknown risks (where the risk has not been identified but industry experience shows that in the course of major projects these can occur. With benefit of hindsight such risks are not considered fully at the time of estimate preparation). The basis for this risk is described in Section 8.4.

6. Functional specification

During the initial phase of this engagement, we drafted a functional specification charting out the structure and organisation of various components of the TCD and explaining how they will interact with each other to produce a cost estimate.

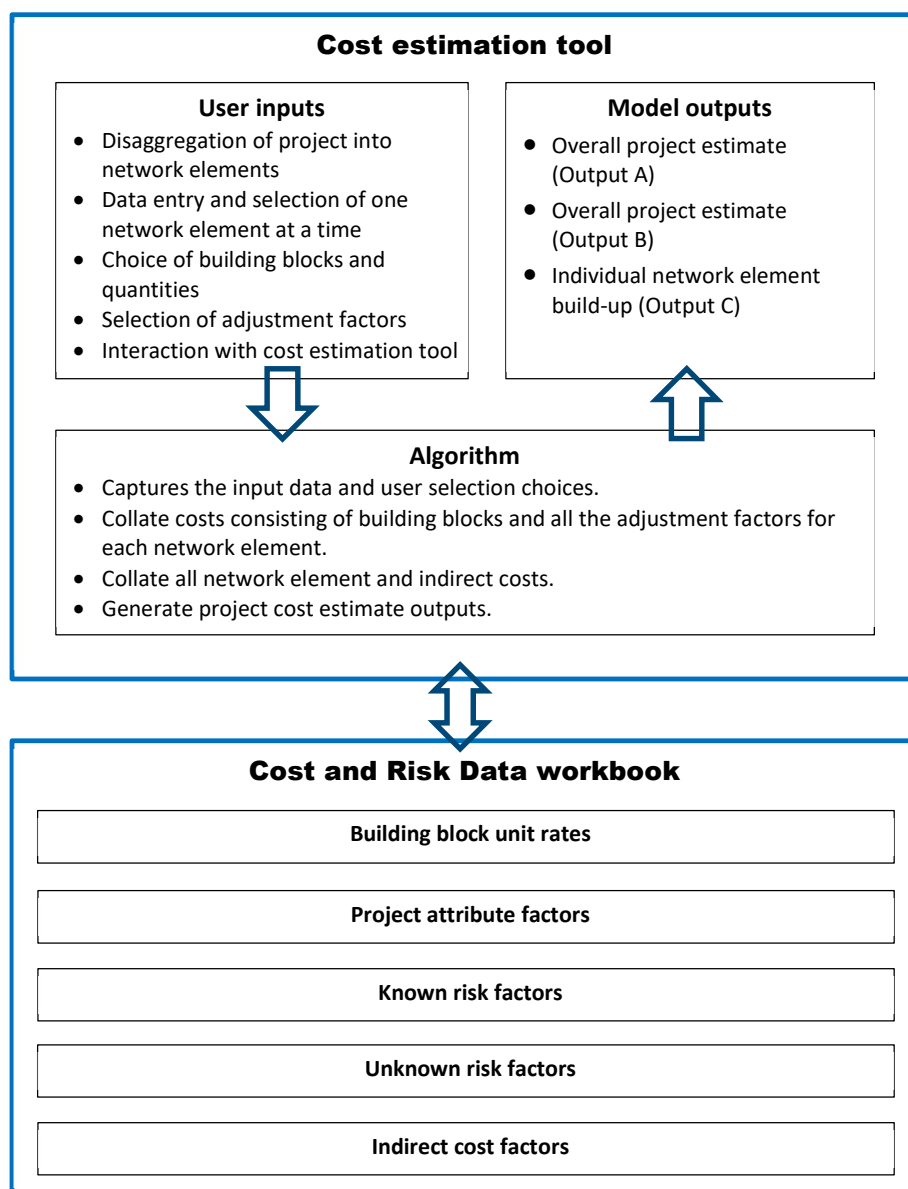
The specification for this interaction driven by user inputs using a cost estimation tool (i.e. ‘dashboard’ or ‘control panel’) were explained.

AEMO reviewed and approved this document, and it provided us the blueprint to develop the TCD. This document is attached in Appendix G and is summarised in the following sub-sections.

6.1 TCD organisation

At the highest level the TCD consists of two separate Excel files – a Cost and Risk Data workbook containing all the fundamental ingredients used to compile a project cost estimate, and a cost estimation tool with interactive ‘Dashboard’ containing algorithms that processes the user inputs and selection choices. The algorithms are written using VBA programming language and macro codes. The separation of the TCD into two separate files was done so for the ease of portability, housekeeping and data protection reasons. The organisation of the TCD is illustrated in the following figure.

Figure 4 TCD organisation



6.2 Cost estimation organisation

The cost estimation performed by the TCD includes the following steps and structure:

- Selection of a number of building blocks and required quantities to match the scope of work for each network element. The building block unit rates represent a Class 5/4 cost estimate without much risk elements² embedded in them. The collection of a number of building block unit rates and associated quantities result in the baseline cost estimate for a given network element. This is referenced as “A” in Table 2 and the characteristics of these building block unit rates are described in detail in Section 6.4.
- The above building block cost estimate for a given network element is adjusted (or modified) based on user specified network element attribute factors. The user selected % attribute factors are multiplied to the baseline cost estimate “A”. This adjustment can be reduction or increment to the above baseline cost estimate. This is referenced as “B” in Table 2 and the characteristics of these factors are described in detail in Section 6.5.
- Network element cost = The above adjusted baseline cost estimate for the network element “B” + Known risk allowance based on user specified risk profile for the network element + Unknown risk allowance based on user specified estimate profile for the network element. This is referenced as “E” in Table 2.

Where: Known risk allowance = user selected known risk % factor × Adjusted baseline cost estimate for the network element “B”. This is referenced as “C” in Table 2 and the characteristics of these factors are described in detail in section 6.6.

Unknown risk allowance = user selected unknown risk % factor × Adjusted baseline cost estimate for the network element “B”. This is referenced as “D” in Table 2 and the characteristics of these factors are described in detail in Section 6.7.

- Total network element cost = $\sum$ All network element costs.
- Total expected project cost = Total network element cost + Indirect costs. This is referenced as “G” in Table 2.

Where: Indirect costs = Predetermined % factor for a given nature of overall project × Total network element cost. This is referenced as “F” in Table 2 and the characteristics of these factors are described in detail in Section 6.8.

This approach is summarised in the following table.

Table 2 TCD estimation organisation

Reference	Cost estimation build-up structure
n	Number of network elements in a project [Project = network element ₁ + network element ₂ + + network element _n]
A	Baseline cost estimate for a given network element
B	Adjusted baseline cost estimate for a given network element
C	Known risk allowance for a given network element
D	Unknown risk allowance for a given network element

² See description in Section 8.1 for specific details.

Reference	Cost estimation build-up structure
E	(B + C + D) for a given network element
$\sum E_{1 \text{ to } n}$	$E_1 + E_2 + \dots + E_n$
F	Indirect costs for the overall project
G	$\sum E_{1 \text{ to } n} + F$

6.3 User input organisation

The user will need to disaggregate their project into distinctive network elements (i.e. network element₁ to network element_n, where n is the number of network elements in a project) and enter the description for each of them. This is performed using the cost estimation tool.

The definition of various terms used in the TCD such as network element, indirect costs, project attributes etc. are provided in the glossary in Appendix B.

For each network element, the use of an interactive dashboard with menus selection in the order of logical description (for e.g. category selection followed by sub-category selection followed by voltage level selection etc.) allows the user to intuitively put together a collection of asset building blocks and quantities to match the given scope of work.

A similar logical order of user selections is to be followed while choosing appropriate adjustment factors for each network element one at a time. This is to be repeated for every network element and finally for the indirect costs.

The sequence of data entry with step-by-step instruction is given in the user manual contained in Appendix C.

6.4 Building block unit rates organisation

The library of various asset building blocks and their unit rates are stored in the Cost and Risk Data workbook. There are approximately 650 unique building blocks organised in categories, sub-categories, voltage level, and further granular description. Each building block unit rate is consistently broken down into 9 cost components. This organisation is summarised for an illustrative purpose in the following table.

Table 3 Extract of building block table in the Cost and Risk Data workbook

Category	Subcategory	Detail	Nominal Voltage kV	Unit	Contractor Project								
					Plant	Civil and structural Works	Electrical Works	Secondary Systems	Design & Survey	Testing & Commissioning	Management & Overheads	Easement/ Property Costs	Environmental Offset Costs
Station	Property site work and built	AIS site infrastructure 5000 m2 foot	N/A	lot	\$ 142,467	\$ 4,986,345	\$ 356,168	\$ 783,569	\$ 142,467	\$ 142,467	\$ 569,868	\$ 2,500	\$ 15,000
Station	Property site work and built	AIS site infrastructure 7500 m2 foot	N/A	lot	\$ 166,213	\$ 5,817,455	\$ 415,533	\$ 914,172	\$ 166,213	\$ 166,213	\$ 664,852	\$ 3,750	\$ 22,500
Station	Property site work and built	AIS site infrastructure 10000 m2 foot	N/A	lot	\$ 191,634	\$ 6,707,190	\$ 479,085	\$ 1,053,987	\$ 191,634	\$ 191,634	\$ 766,536	\$ 5,000	\$ 30,000
Station	Property site work and built	AIS site infrastructure 15000 m2 foot	N/A	lot	\$ 247,501	\$ 8,662,535	\$ 618,753	\$ 1,361,256	\$ 247,501	\$ 247,501	\$ 990,004	\$ 7,500	\$ 45,000
Station	Property site work and built	AIS site infrastructure 20000 m2 foot	N/A	lot	\$ 310,068	\$ 10,852,380	\$ 775,170	\$ 1,705,374	\$ 310,068	\$ 310,068	\$ 1,240,272	\$ 10,000	\$ 60,000
Station	Property site work and built	AIS site infrastructure 25000 m2 foot	N/A	lot	\$ 379,335	\$ 13,276,725	\$ 948,338	\$ 2,086,343	\$ 379,335	\$ 379,335	\$ 1,517,340	\$ 12,500	\$ 75,000
Station	Property site work and built	AIS site infrastructure 30000 m2 foot	N/A	lot	\$ 455,302	\$ 15,935,570	\$ 1,138,255	\$ 2,504,161	\$ 455,302	\$ 455,302	\$ 1,821,208	\$ 15,000	\$ 90,000
Station	Property site work and built	AIS site infrastructure 35000 m2 foot	N/A	lot	\$ 537,969	\$ 18,828,915	\$ 1,344,923	\$ 2,958,830	\$ 537,969	\$ 537,969	\$ 2,151,876	\$ 17,500	\$ 105,000
Station	Secondary system building	Demountable building 14 x 3 x 4m s	N/A	ea.	\$ 357,500	\$ 143,000	\$ 32,500	\$ 65,000	\$ 13,000	\$ 13,000	\$ 26,000	\$ -	\$ -
Station	Secondary system building	Demountable building 12 x 3 x 4m s	N/A	ea.	\$ 343,750	\$ 137,500	\$ 31,250	\$ 62,500	\$ 12,500	\$ 12,500	\$ 25,000	\$ -	\$ -
Station	Secondary system building	Demountable building 10 x 3 x 4m s	N/A	ea.	\$ 330,000	\$ 132,000	\$ 30,000	\$ 60,000	\$ 12,000	\$ 12,000	\$ 24,000	\$ -	\$ -
Station	AIS Switchbay	3CB Diameter 3CBs	500	lot	\$ 2,302,000	\$ 1,485,150	\$ 546,000	\$ 300,000	\$ 463,315	\$ 92,663	\$ 572,657	\$ -	\$ -
Station	AIS Switchbay	3CB Diameter 2CBs	500	lot	\$ 1,547,000	\$ 1,310,100	\$ 384,000	\$ 200,000	\$ 344,110	\$ 68,822	\$ 425,320	\$ -	\$ -
Station	AIS Switchbay	3CB Diameter 1CB	500	lot	\$ 807,000	\$ 1,135,050	\$ 222,000	\$ 100,000	\$ 226,405	\$ 45,281	\$ 279,837	\$ -	\$ -

The 9 cost components of the building block unit rates are as follows:

- Plant (supply of primary material assets such as steel towers, equipment, conductors, switchgear, cables etc.)
- Civil and structural works (supply of civil infrastructure assets and installation works such as earthworks, buildings, foundation, busbar, gantry, clearing, access tracks etc.)

- Electrical works (supply of electrical installation works such as stringing, fitting, termination, jointing, lighting etc.)
- Secondary systems (supply of secondary system material assets such as relays, control panels, protection panels, SCADA, station batteries etc.)
- Design & survey (supply of engineering and environmental design and survey works towards the front end of the project life cycle phase)
- Testing & commissioning (supply of electrical, civil and structural assurance works towards the back end of the project life cycle prior to operational approval of the constructed assets)
- Contractor project management & overheads (supply of the site supervision, resource mobilisation, site set-up, project management and related expenses by the hired contractors)
- Easement and property acquisition costs (procurement of easement right of way and land acquisition by the project proponents)
- Environmental offset costs (costs to compensate for unavoidable environmental and biodiversity impacts due to the project works).

Please refer to the description and note columns in the Cost and Risk Data workbook for further details on each building block unit rate and its scope. The same detail also appears in the description and note fields in the cost estimation tool dashboard.

6.5 Project attribute factors organisation

The library of project attributes and their percentage factors impacting the 9 cost components of building block unit rate are stored in the Cost and Risk Data workbook. There are 10 unique project attribute factors respectively organised in the same set of categories (station, overhead lines and underground cables) as was used for the building blocks. Each project attribute factor has multiple choices (for e.g. short, medium, long) for the user to select, with each choice having a unique set of percentage factor impacting the set of 9 cost components. This organisation is summarised for an illustrative purpose in the following table.

Table 4 Extract of project attribute table in the Cost and Risk Data workbook

Category	Subcategory	Detail	Plant	Civil and structural Works	Electrical Works	Secondary Systems	Design & Survey	Testing & Commissioning	Project Management & Overheads	Easement/Property Costs	Environmental Offset Costs
1 Station project attribute	Jurisdiction	NSW	-	-	-	-	-	-	-	-	-
2 Station project attribute	Jurisdiction	QLD	-	-	-	-	-	-	-	-	-15.00%
3 Station project attribute	Land Use	Desert	-	-	-	-	-	-	-	3.00%	-
4 Station project attribute	Land Use	Scrub	-	-	-	-	-	-	-	20.00%	-
5 Station project attribute	Land Use	Grazing	-	-	-	-	-	-	-	50.00%	-
6 Station project attribute	Land Use	Developed Area	-	-	-	-	-	-	-	100.00%	-
7 Station project attribute	Greenfield or Brownfield	Greenfield	-	-	-	-	-	-	-	-	-
8 Station project attribute	Greenfield or Brownfield	Partly Brownfield	-	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	-	-
9 Station project attribute	Greenfield or Brownfield	Brownfield	-	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	-	-
10 Station project attribute	Proportion of Environmentally Sensitive Area	None	-	-	-	-	-	-	-	-	-
11 Station project attribute	Proportion of Environmentally Sensitive Area	25 percent	-	-	-	-	-	-	0.05%	-	-
12 Station project attribute	Proportion of Environmentally Sensitive Area	50 percent	-	-	-	-	-	-	0.10%	-	-
13 Station project attribute	Proportion of Environmentally Sensitive Area	75 percent	-	-	-	-	-	-	0.15%	-	-

The 10 project attribute factors are as follows:

- Project network element size (this is an economy of scale factor for the overall project)
- Jurisdiction
- Land use
- Greenfield or brownfield
- Proportion of environmentally sensitive area
- Location (regional/distance factor)

- Location wind loading zones
- Delivery timetable
- Contract delivery model
- Terrain.

Please refer to the description and note columns in the Cost and Risk Data workbook for further details on the attribute factors, their scope and its respective user selection choices. The same detail also appears in the description and note fields in the cost estimation tool dashboard.

6.6 Known risk factors organisation

The library of known risks and their percentage factors impacting the 9 cost components of building block unit rate are stored in the Cost and Risk Data workbook. There are 9 unique known risk factors respectively organised in the same set of categories (station, overhead lines and underground cables) as was used for the building blocks. Each known risk factor has multiple choices (for e.g. low, BAU, high) for the user to select, with each choice having a unique set of percentage factor impacting the set of 9 cost components. This organisation is summarised for an illustrative purpose in the following table.

Table 5 Extract of known risk table in the Cost and Risk Data workbook

			Project									
Category	Subcategory	Detail	Plant	Civil and structural Works	Electrical Works	Secondary Systems	Design & Survey	Testing & Commissioning	Management & Overheads	Easement/Property Costs	Environmental Offset Costs	
Station known risk	Macroeconomic influence	BAU	-	-	-	-	-	-	-	-	-	
Station known risk	Macroeconomic influence	Increased Uncertainty	2.0%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	-	-	
Station known risk	Macroeconomic influence	Heightened Uncertainty	3.0%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	-	-	
Station known risk	Market Activity	Excess Capacity	-	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-5.0%	-	-	
Station known risk	Market Activity	BAU	-	-	-	-	-	-	-	-	-	
Station known risk	Market Activity	Tight	-	1.0%	1.0%	1.0%	1.0%	1.0%	5.0%	-	-	
Station known risk	Project complexity	BAU	-	-	-	-	-	-	-	-	-	
Station known risk	Project complexity	Partly complex	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	-	-	
Station known risk	Project complexity	Highly complex	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	-	-	
Station known risk	Compulsory Acquisition	Low	-	-	-	-	-	-	-	-10.0%	-	
Station known risk	Compulsory Acquisition	Expected Historically	-	-	-	-	-	-	-	-	-	
Station known risk	Compulsory Acquisition	High	-	-	-	-	-	-	-	20.0%	-	
Station known risk	Environmental Offset Risks	Low	-	-	-	-	-	-	-	-	-	
30.0%												

The 9 known risk factors are as follows:

- Macroeconomic influence
- Market activity
- Project complexity
- Compulsory acquisition
- Environmental offset risks
- Geotechnical findings
- Outage restrictions
- Weather delays
- Cultural heritage.

Please refer to the description and note columns in the Cost and Risk Data workbook for further details on the known risk factors, their scope and its respective user selection choices. The same detail also appears in the description and note fields in the cost estimation tool dashboard.

6.7 Unknown risk factors organisation

The library of unknown risks and their percentage factors impacting the 9 cost components of building block unit rate are stored in the Cost and Risk Data workbook. There are 4 unique unknown risk factors respectively organised in the same set of categories (station, overhead lines and underground cables) as was used for the building blocks. Each unknown risk factor has multiple choices (for e.g. Class 5, 4, 3 etc.) for the user to select, with each choice having a unique set of percentage factors impacting the set of 9 cost components. This organisation is summarised for an illustrative purpose in the following table.

Table 6 Extract of unknown risk table in the Cost and Risk Data workbook

Category	Subcategory	Detail	Project								
			Plant	Civil and structural Works	Electrical Works	Secondary Systems	Design & Survey	Testing & Commissioning	Management & Overheads	Easement/Property Costs	Environmental Offset Costs
Station unknown risk	Scope and Technology Risks	Class 5	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%	-	30.0%	30.0%
Station unknown risk	Scope and Technology Risks	Class 4	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	-	20.0%	20.0%
Station unknown risk	Scope and Technology Risks	Class 3	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	-	10.0%	10.0%
Station unknown risk	Scope and Technology Risks	Class 1/2	-	-	-	-	-	-	-	-	-
Station unknown risk	Productivity and Labour Cost Risks	Class 5	-	4.0%	4.0%	4.0%	4.0%	4.0%	-	-	-
Station unknown risk	Productivity and Labour Cost Risks	Class 4	-	3.0%	3.0%	3.0%	3.0%	3.0%	-	-	-
Station unknown risk	Productivity and Labour Cost Risks	Class 3	-	1.0%	1.0%	1.0%	1.0%	1.0%	-	-	-
Station unknown risk	Productivity and Labour Cost Risks	Class 1/2	-	-	-	-	-	-	-	-	-
Station unknown risk	Plant Procurement Cost Risks	Class 5	4.0%	-	-	-	-	-	-	-	-
Station unknown risk	Plant Procurement Cost Risks	Class 4	3.0%	-	-	-	-	-	-	-	-
Station unknown risk	Plant Procurement Cost Risks	Class 3	1.0%	-	-	-	-	-	-	-	-
Station unknown risk	Plant Procurement Cost Risks	Class 1/2	-	-	-	-	-	-	-	-	-
Station unknown risk	Project Overhead Risks	Class 5	-	-	-	-	-	-	4.0%	15.0%	15.0%
Station unknown risk	Project Overhead Risks	Class 4	-	-	-	-	-	-	3.0%	10.0%	10.0%
Station unknown risk	Project Overhead Risks	Class 3	-	-	-	-	-	-	1.0%	5.0%	5.0%
Station unknown risk	Project Overhead Risks	Class 1/2	-	-	-	-	-	-	-	-	-

The 4 unknown risk factors are as follows:

- Scope and technology risks (this is scope or quantity factor)
- Productivity and labour cost risks (this is the unit cost factor)
- Plant procurement cost risks (this is the unit cost factor)
- Project overhead risks (this is the unit cost factor).

Please refer to the description and note columns in the Cost and Risk Data workbook for further details on the unknown risk factors, their scope and its respective user selection choices. The same detail also appears in the description and note fields in the cost estimation tool dashboard.

6.8 Indirect cost factors organisation

The indirect cost represents the owner internal costs and is broken down into 6 cost components to match the various functions and cost centres within the owners' business. It represents all costs not covered by the contractors or suppliers. Unlike project attributes and risks, the indirect cost is applied to the overall project cost (i.e. after the estimation of all network element costs). A unique set of percentage factors are applied to the 6 cost components depending on a number of project characteristics. This list of project characteristics with their percentage factors to calculate the 6 cost components are stored in the Cost and Risk Data workbook. This organisation is summarised for an illustrative purpose in the following table.

Table 7 Extract of indirect costs table in the Cost and Risk Data workbook

Category	Subcategory	Detail	Project		Land and Environment	Stakeholder and Community Engagement	Procurement Costs	Insurance	Total allowance for indirect costs
			Development	Works Delivery					
Indirect Cost (to be applied to overall total project)	Greenfield	Below \$50 million	6.40%	2.56%	2.72%	1.76%	1.60%	0.96%	16.00%
Indirect Cost (to be applied to overall total project)	Greenfield	\$50-\$100 million	5.32%	2.13%	2.26%	1.46%	1.33%	0.80%	13.30%
Indirect Cost (to be applied to overall total project)	Greenfield	\$100-\$500 million	4.00%	1.60%	1.70%	1.10%	1.00%	0.60%	10.00%
Indirect Cost (to be applied to overall total project)	Greenfield	\$500-\$1000 million	3.20%	1.28%	1.36%	0.88%	0.80%	0.48%	8.00%
Indirect Cost (to be applied to overall total project)	Greenfield	\$1000-\$1500 million	2.80%	1.12%	1.19%	0.77%	0.70%	0.42%	7.00%
Indirect Cost (to be applied to overall total project)	Greenfield	Above \$1500 million	2.60%	1.04%	1.11%	0.72%	0.65%	0.39%	6.50%
Indirect Cost (to be applied to overall total project)	Partly Brownfield	Below \$50 million	5.92%	4.64%	2.00%	1.44%	1.20%	0.80%	16.00%
Indirect Cost (to be applied to overall total project)	Partly Brownfield	\$50-\$100 million	4.92%	3.86%	1.66%	1.20%	1.00%	0.67%	13.30%
Indirect Cost (to be applied to overall total project)	Partly Brownfield	\$100-\$500 million	3.70%	2.90%	1.25%	0.90%	0.75%	0.50%	10.00%
Indirect Cost (to be applied to overall total project)	Partly Brownfield	\$500-\$1000 million	2.96%	2.32%	1.00%	0.72%	0.60%	0.40%	8.00%
Indirect Cost (to be applied to overall total project)	Partly Brownfield	\$1000-\$1500 million	2.59%	2.03%	0.88%	0.63%	0.53%	0.35%	7.00%
Indirect Cost (to be applied to overall total project)	Partly Brownfield	Above \$1500 million	2.41%	1.89%	0.81%	0.59%	0.49%	0.33%	6.50%
Indirect Cost (to be applied to overall total project)	Brownfield	Below \$50 million	5.44%	6.72%	1.28%	1.12%	0.80%	0.64%	16.00%
Indirect Cost (to be applied to overall total project)	Brownfield	\$50-\$100 million	4.52%	5.59%	1.06%	0.93%	0.67%	0.53%	13.30%

The 6 cost components of the indirect costs are as follows:

- Project development (costs incurred to perform feasibility studies, option analysis, regulatory investment tests etc.)
- Works delivery (cost incurred to perform preliminary investigations, site inspections, survey, conceptual design work, site supervision, safety assurance, contract management, commissioning etc.)
- Land and environment (management and administration costs to procure easement right of way, land and environmental offsets)
- Stakeholder and community engagement (management and administration costs to liaise and engage with various project stakeholders and impacted communities)
- Procurement costs (management and administration costs to organise, tender, evaluate and award contracts)
- Insurance (costs incurred to obtain project insurance).

Please refer to the description and note columns in the Cost and Risk Data workbook for further details on indirect cost factors and their scope. The same detail also appears in the description and note fields in the cost estimation tool dashboard.

For avoidance of doubt, the indirect costs do not include the finance cost. The finance cost and its arrangement are a corporate finance and cashflow modelling subject matter. This is different and separate to the cost estimation topic and deals with debt/equity gearing, beta, interest rate, tax shielding etc. We consider that finance cost should not be involved or included in the capital project cost estimation. Our view is consistent with the following observations:

- The AER's revenue building block model treats finance cost (in the Weighted Average Cost of Capital or WACC) and capex estimate (in the RAB) as separate items to calculate the return on capital. Accordingly, the AER's PTRM model treats finance cost as a separate item from capex estimate. If the finance cost is included in the capex estimate, then it will be double counted.
- In investment cost benefit analysis using net present value model, the AER's RIT-T guideline suggest using regulated industry WACC as the lower bound discount rate and the commercial discount rate as the upper bound. It is this parameter that should be used consistently to assess the investment attractiveness of the project options.
- Observation of the recent transmission augmentation projects in the NEM excluded the finance cost from its capital project cost estimates build-up.
- The investment decision should be independent of the financing decision, i.e. the project capex estimate (investment) should be independent of the mix of methods – equity, debt, bond, cash etc. – used to finance the project.

6.9 Output display organisation

The TCD produces the following three styles of output displays:

- **Output A** provides a high-level summary of each network element cost estimate and the indirect costs to reach the total expected project cost. Each network element cost estimate summary is inclusive of the respective chosen scope attribute and risk adjustment factors. This display is illustrated in Figure 5. It shows an example extract where the project has been disaggregated into three distinctive network elements with the breakdown of the indirect costs.

Figure 5 Illustration of output A

Network element	Total Network Element costs
500kV Converter Station 1	\$ 484.12 M
500kV Converter Station 2	\$ 469.92 M
500kV HVDC Line	\$ 861.54 M
Total Network Element Cost	\$ 1815.58 M
Indirect Costs	
Project Development	\$ 47.21 M
Works Delivery	\$ 18.88 M
Land and Environment	\$ 20.06 M
Stakeholder and Community Engagement	\$ 12.98 M
Procurement Costs	\$ 11.80 M
Insurance	\$ 7.08 M
Total Indirect Cost	\$ 118.01 M
Total Expected Project Cost	\$ 1933.59 M

- **Output B** provides an alternative high-level summary of the sum of all the network element cost estimate (baseline cost), its adjustment after project attribute application (adjusted baseline cost), known risk allowance, unknown risk allowance, and the indirect costs to reach the total expected project cost. Each cost item summary includes the respective items of all the network elements. This display is illustrated in Figure 6. This display format remains unchanged irrespective of the number of network elements used.

Figure 6 Illustration of output B

	Total Expected Costs
Baseline Cost	\$ 1491.48 M
Adjusted Baseline Cost	\$ 1483.11 M
Known Risk Allowance	\$ 95.99 M
Unknown Risk Allowance	\$ 236.48 M
Total Network Element Cost	\$ 1815.58 M
Indirect Costs:	
Project Development	\$ 47.21 M
Works Delivery	\$ 18.88 M
Land and Environment	\$ 20.06 M
Stakeholder and Community Engagement	\$ 12.98 M
Procurement Costs	\$ 11.80 M
Insurance	\$ 7.08 M
Total Indirect Cost	\$ 118.01 M
Total Expected Project Cost	\$ 1933.59 M

- **Output C** provides the most granular cost estimate build-up detail for every network element within the project. It lists all the inputs selected and entered by the user (i.e. category, sub-category, menu selection, quantities etc. for building block, project attributes, known risks and unknown risks) used to compile the cost estimate for each network element. As such, this display is also a record of the inputs. This display does not include the indirect costs as it sits outside the individual network element level and is applied to the sum of all network elements. This display is illustrated in Figure 7. It shows an example extract of only one network element. The actual output C will have series of such display for every network element.

Figure 7 Illustration of output C

Network Element 1 500kV Converter Station 1																
Category		Subcategory	Details	Nominal Voltage	Qty	UOM	Plant and Materials	Civil and Structural Works	Electrical Works	Secondary Systems	Design & Survey	Testing & Commissioning	Contractor Project Management & Overheads	Easement/Property Costs	Environmental Offset Costs	Total Network Element costs
Building Blocks:	Station	Property site work and building	AS site infrastructure 35000 m2 loopline area and applicable control building	N/A	1	lot	\$ 0.54 M	\$ 18.83 M	\$ 1.34 M	\$ 2.36 M	\$ 0.54 M	\$ 0.54 M	\$ 2.15 M	\$ 0.02 M	\$ 0.11 M	\$ 27.02 M
	Station	AS Switchbay	3CB Diameter 2CBs	500	2	lot	\$ 3.09 M	\$ 2.82 M	\$ 0.77 M	\$ 0.40 M	\$ 0.69 M	\$ 0.14 M	\$ 0.85 M	\$ 0.00 M	\$ 0.00 M	\$ 8.58 M
	Station	AS Switchbay	3CB Diameter 3CBs	500	2	lot	\$ 4.60 M	\$ 2.37 M	\$ 1.09 M	\$ 0.60 M	\$ 0.30 M	\$ 0.15 M	\$ 1.15 M	\$ 0.00 M	\$ 0.00 M	\$ 11.52 M
	Station	HVDC converters - VSC	2+ Asymmetrical Monopole (Bipole), 2 + 1000MW	±500	1	lot	\$ 190.27 M	\$ 49.91 M	\$ 12.48 M	\$ 21.83 M	\$ 24.26 M	\$ 6.24 M	\$ 41.59 M	\$ 0.00 M	\$ 0.00 M	\$ 346.57 M
Baseline Cost							\$ 198.51 M	\$ 74.33 M	\$ 15.68 M	\$ 25.79 M	\$ 26.41 M	\$ 7.10 M	\$ 45.74 M	\$ 0.02 M	\$ 0.11 M	\$ 393.68 M
Adjustments:	Station project attribute	Contract Delivery Model	EPC contract	-	-	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Station project attribute	Delivery Timetable	Optimum	-	-	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Station project attribute	Greenfield or Brownfield	Greenfield	-	-	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Station project attribute	Proportion of Environmentally Sensitive Areas	50 percent	-	-	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.00%	0.00%	0.00%
	Station project attribute	Jurisdiction	VIC	-	-	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-5.00%	0.00%
	Station project attribute	Land Use	Developed Area	-	-	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
	Station project attribute	Location (Regional/distance factors)	Urban	-	-	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Station project attribute	# of total Bays above 311 applicable for HVDC converter station project		-	-	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Station project attribute	Project Network Element Size		-	-	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-5.00%
	Total Adjustment Rate %							0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	100.00%	-5.00%
Adjusted Baseline							\$ 198.51 M	\$ 74.33 M	\$ 15.68 M	\$ 25.79 M	\$ 26.41 M	\$ 7.10 M	\$ 45.76 M	\$ 0.04 M	\$ 0.10 M	\$ 393.74 M
Known Risks:	Station known risk	Cultural Heritage	BAU				0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Station known risk	Environmental Offset Risks	BAU				0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	30.00%
	Station known risk	Project complexity	Highly complex				8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	0.00%	0.00%
Total Known Risk Rate %							8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	0.00%	30.00%
Local Known Risk Rate \$							\$ 16.28 M	\$ 6.69 M	\$ 1.41 M	\$ 2.06 M	\$ 2.11 M	\$ 0.57 M	\$ 0.83 M	\$ 0.00 M	\$ 0.03 M	\$ 32.04 M
Subtotal Including Known Risks							\$ 214.78 M	\$ 81.02 M	\$ 17.09 M	\$ 27.85 M	\$ 28.53 M	\$ 7.67 M	\$ 49.47 M	\$ 0.04 M	\$ 0.13 M	\$ 428.57 M
Unknown Risks:	Station unknown risk	Plant Procurement Cost Risks	Class 5				4.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Station unknown risk	Productivity and Labour Cost Risks	Class 5				0.00%	4.00%	4.00%	4.00%	4.00%	4.00%	0.00%	0.00%	0.00%	0.00%
	Station unknown risk	Project Overhead Risks	Class 5				0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.00%	15.00%	15.00%	0.00%
	Station unknown risk	Scope and Technology Risks	Class 5				12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	0.00%	30.00%	30.00%	0.00%
Total Unknown Risk Rate %							16.00%	16.00%	16.00%	16.00%	16.00%	16.00%	4.00%	45.00%	45.00%	0.00%
Total Unknown Risk Rate \$							\$ 31.76 M	\$ 11.89 M	\$ 2.51 M	\$ 4.13 M	\$ 4.23 M	\$ 1.14 M	\$ 1.83 M	\$ 0.02 M	\$ 0.04 M	\$ 57.54 M
Total Expected Network Element							\$ 246.54 M	\$ 92.91 M	\$ 19.60 M	\$ 31.98 M	\$ 32.75 M	\$ 8.80 M	\$ 51.30 M	\$ 0.05 M	\$ 0.17 M	\$ 484.12 M

7. Data request template

In order to benchmark cost estimates generated by the newly developed TCD, we drafted two data request templates (excel tables) – one for stations and one for overhead lines/underground cables reflecting the non-linear and linear types of capital projects.

Both of these templates are summarised or aggregated at a fairly high level and generally match the style and breakdown of the cost information used in the NEM regulatory submission and review process. Blank versions of these data request templates are shown in Appendix E.

These two templates were provided to the TNSPs and the AER with the aim to collect the cost information of recently estimated major projects in a consistent manner to aid benchmarking activity. We requested various cost estimate versions of projects that have progressed to advanced investment decision stage representing the maturing estimate from Class 5 to Class 3.

We requested the advance stage cost estimate to draw conclusions on the application and refinement of risks in the TCD based on variations in estimates progressing from earlier stage cost estimates and for benchmarking the outputs of the TCD.

While we could not obtain the cost information of all the identified and requested projects from the TNSPs and the AER, we receive some examples of both types of cost estimates (i.e. advanced and early stage) to proceed with benchmarking.

The received examples contained diversity of capital works in their respective network elements including HVAC, HVDC, station and overhead lines. This allowed us to test and calibrate the variables (building block unit cost estimate, project attribute adjustment and risks allocation) and the calculation logic used in the TCD.

8. Basis of cost estimate

The formulation of the cost estimates generated by the TCD is made up of various elements stored in the Cost and Risk Data workbook and how they interact with each other driven by user inputs and selections using the cost estimation tool. This is explained in section 6. In this section we explain the basis of those various elements and the methodology we used in determining them.

8.1 Building blocks

There are approximately 650 unique building blocks in the Cost and Risk Data workbook grouped into 3 network element categories (station, overhead lines and underground cables) and 26 sub-categories in total. They are summarised in section 6.4.

The breakdown structure of the building block is aligned to the AEMO's specification. In general, the unit rate estimates for these building blocks were derived from various sources and our experience as listed below:

- GHD's electricity network project bottom-up cost estimation model that uses various sources such as Rawlinson civil construction handbook, labour hours, contractor cost allocation and OEM material procurement quotes
- Publicly available cost estimate information for given scopes of work in the NEM during the revenue reset and RIT-T determination process
- Independent verification of various major transmission projects that GHD has recently undertaken in Australia enabling us to appreciate the build-up of costs including assets of various type, contractor costs, mobilisation costs and fixed cost structures
- Leveraging our global skill sets to obtain additional comparative cost information and specifically on HVDC technology projects undertaken in England, Europe and North America
- Leveraging our multidisciplinary skill sets to understand the nuances of environmental regulatory requirements, associated offset costs and how it may impact in various NEM jurisdictions for different types of projects
- Using our judgement, knowledge and opinion to extrapolate estimates with available or known information in instances where cost information was missing.

With reference to the above, certain types of cost information were given priority (higher weighting) when estimating and compiling the unit rates of building blocks. For example:

- Actual project cost records, or OEM quotes against specified scope of asset, or contractor tendered fee against a scope of work were given the highest priority over estimated costs
- Recent cost information over an older set of information. In the absence of any recent cost information, the available historic cost information was escalated using price indices to convert into 2021 dollar value
- International projects were converted into nominal Australian dollar value (i.e. 2021 \$) and adjustments made for comparative labour costs between countries
- Multiple sources of comparative estimates were used to a large extent to support the established unit rates while applying weighting to the cost information based on the comparative level of accuracy.

Some of the building block unit rates were further calibrated after benchmarking with the cost estimate information collected from the TNSPs.

This basis of estimate and age of the source data is identified and described for every building block item in the Cost and Risk Data workbook.

With reference to the above, we were conscious of not double counting risk allowances in the cost build ups and establishing clear definitions for building block unit rates and the risks. The general definition of a building block unit cost is:

- The expected unit costs for a successful contractor, following a tendering process, to deliver the defined scope of work, or the final owner costs in the case of indirect costs, or the final Class 3 estimate of property and environmental offset costs, less
- The industry average unknown risks for unit costs (this is added back in the TCD as unknown risks to align with the Class 5 estimate structure).

It is important to note that unknown risk due to scope changes (or unknown scope risks³) do not affect the building block unit rates. As discussed later in section 8.4, there has been a tendency to underestimate project costs in Class 5 estimates, and this is caused by both scope change and cost change (or unknown cost risks⁴) to that allowed in earlier estimates. The application of the unknown risks allows for these historical variations.

In the TCD, unknown scope risks are selected on the basis of the level of scope definition accuracy. If the size or quantity of building block increases (e.g. km of line) due to higher scope definition, then the entry for unknown scope risks will need to be reduced.

Therefore, the building block unit rate represents a base cost for the defined scope of work. The 'best estimate' generated by the TCD then aims to approximate a Class 3 estimate by adding the known and unknown risks to the base costs after adjusting with project specific attributes.

For simplicity the building blocks unit rate do inherently include the delivery risks typically priced by a contractor. The known risks within the TCD therefore represents residual delivery risks, historically seen and experienced by the project proponents.

When capturing industry cost information, the earlier Class 5 delivery risks and unknown cost risks are innately priced into the scope of work for the given network costs by project proponents in Class 3 estimates.

8.2 Project attributes

There are 10 unique project attributes for each of the 3 categories (station, overhead lines and underground cables). They are summarised in section 6.5. The list of project attributes is aligned to the AEMO's specification. In general, the allowance factors for these project attributes were derived using our experience of electricity network infrastructure projects in a range of roles and using the following basis:

- Differences in contractor tender fee and cost estimates used by TNSPs for the same project outcome under different circumstances (e.g. line length, terrain, land use)
- Difference in supplier/OEM handling fee for delivery of goods to various locations
- Differences in labour productivity under different circumstances and to work under constraint scenario (for e.g. design with high interface, safety zone, traffic restriction, excavation speed etc.)
- Rawlinson civil construction handbook regional indices

³ This is referred to as Scope and technology risks in the TCD.

⁴ These are referred to as Productivity and labour cost risks, Plant procurement cost risks, and Project overhead risks in the TCD

- Difference in services procurement cost representing efficient pricing achieved via economy of scale, longer term or volume certainty panel order contract etc
- Using our judgement, knowledge and opinion to extrapolate allowance factor with available or known information in instances where such information was missing.

Some of the building block unit rates adjusted by applying some of the project attribute factors were benchmarked with the cost estimate information (with qualification of project attribute) collected from the TNSPs.

8.3 Known risks

For known risk factors, that are evident at the current stage of an estimate, an approach to assessing the cost impact and effective probabilities has been adopted for the TCD using experienced judgement and historic project data.

A set of 9 known risk factors for each of the 3 categories (station, overhead lines and underground cables) and their respective selection choices (proxy for probabilities) have been adopted for the TCD. This aligned with the AEMO's specification. This results in known risks being estimated using 'top-down' percentage of project cost.

The percentage factor for known risks would be greater for a quantity and cost based Class 5 estimate than for a Class 4 or Class 3 estimate.

Known risk factors, by definition, will be evident at the current stage of an estimate and will consist of delivery related risks and known complexities in scope that will tend to be priced in by contractors during later tender stages.

In a quantity and cost based Class 5 estimate, the following delivery risks would need to be considered:

- The price elasticity in the market with varying level of resource supply and demand.
- Operational constraints involved in field construction and connection activities.

Within the TCD the allowance for these known costs and risks are inherently included in the building blocks and attributes, hence the known risks in the TCD are comparable to residual risks that the project proponent retains at the revenue determination stage.

Generally, linear construction activities (i.e. overhead lines and underground cables) are exposed to more uncertainties or risks than a site-specific construction works (i.e. station). Some of the known risks (e.g. compulsory property/easement acquisition) will have eventuated (or stopped to exist) by the time the project estimate reaches Class 2 or 1 stage. Some known risks will continue to exist, with potential to eventuate, even during the delivery of the project (e.g. wet weather delays). While other known risks such as forex and commodity price escalation (which is summarised by the macroeconomic influence factor) will continue to exist with potential to eventuate during project delivery but can be or are usually mitigated using financial instruments and procurement contractual terms.

The percentage values for the known risk factors have been derived using our experience of electricity network infrastructure projects in a range of roles and using our understanding of additional costs (labour effort, schedule, overheads) needed to own and manage known risks and variations from suppliers, service providers and contractors. These risks include only the risks categories that the AER will accept within final revenue determinations.

Some of the known risk factors application were benchmarked against the cost estimate information (with qualification of project attributes) collected from TNSPs.

8.4 Unknown risks

A set of 4 unknown risk factors for each of the 3 categories (station, overhead lines and underground cables) and their respective selection choices (proxy for probabilities) has been adopted for the TCD. This results in unknown risks being estimated using a 'top-down' percentage of network element costs.

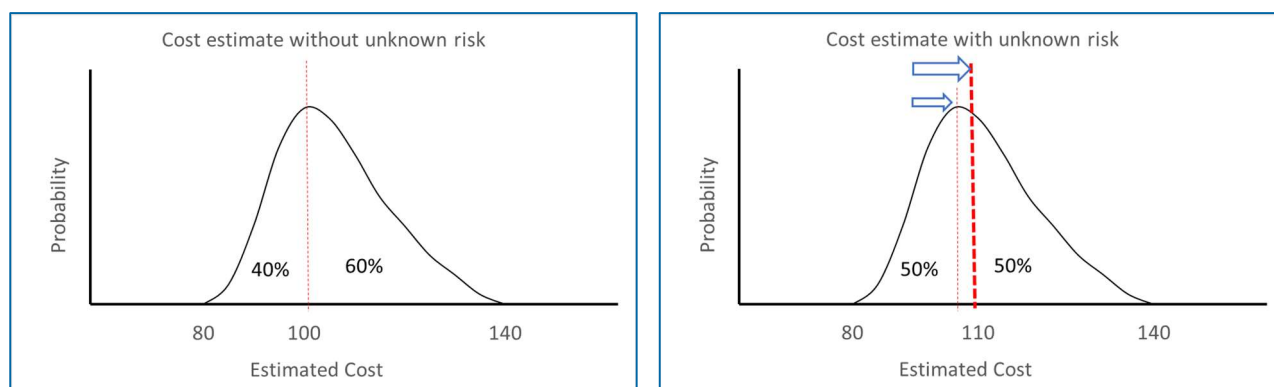
Developing an approach to derive an estimate for unknown risk factors (or also referred to as 'contingency') is more problematic by definition – we do not know what the risks are, and we may only know either the cost impact and not the probability or vice versa. At worse we will not know either.

However, we know the probability distribution of the variation of costs that occurs in infrastructure projects, including past distribution augmentation projects and recent transmission augmentation estimates, from early to final/advanced estimated costs. Most cost predictions or estimates for infrastructure projects demonstrate some measure of asymmetrical distribution or skewness, usually to the high side where the probability of overrun is higher than the probability of underrun.

Unknown risk factor or contingency is thus usually a positive allowance added to cover the variability surrounding the base estimate in quantity and cost base Class 5 estimates, and to equalise the chance of project overrunning and underrunning from the best estimate of project costs.

The inclusion of unknown risk (contingency) in the cost estimate does not change the overall accuracy range of that estimate; it however compensates the accuracy offset so that there is equal chance of the project cost coming over and under the estimate. This is illustrated in the following figure, where the area under the curve on either side of the dashed line represents the likelihood that the final outcome cost will be less than or greater than the estimated cost.

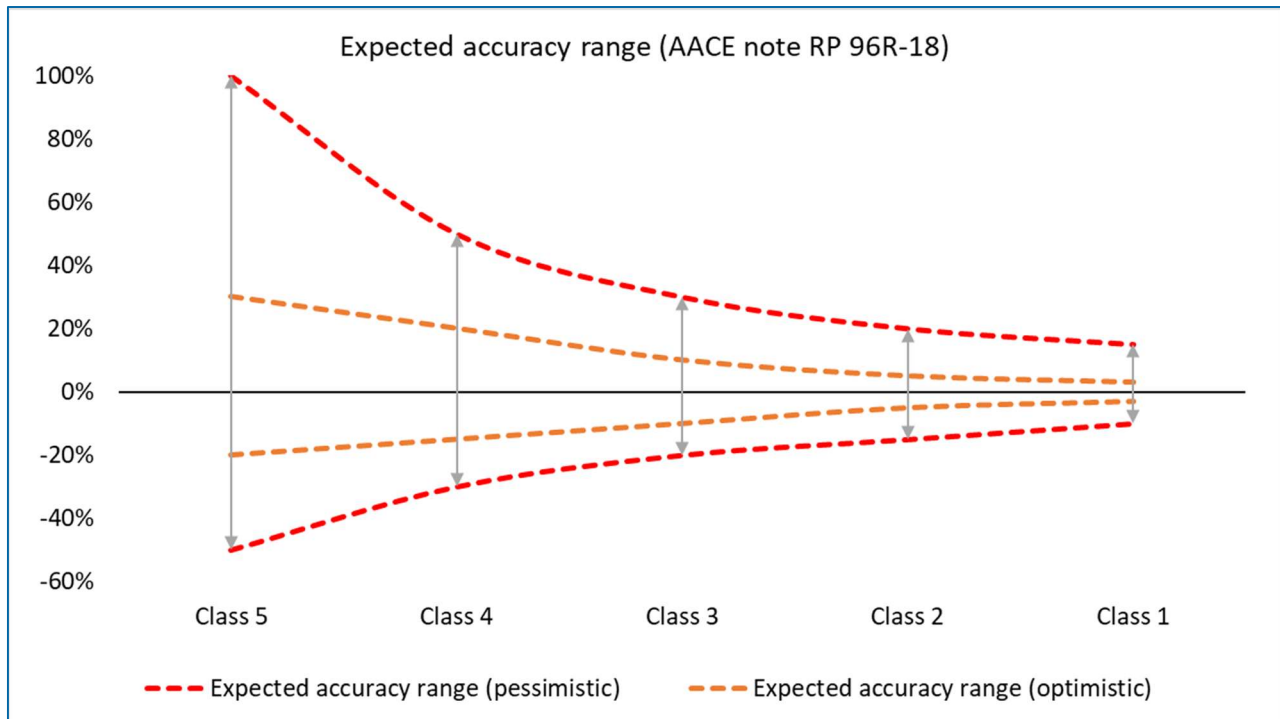
Figure 8 Application of unknown risk in cost estimate (illustration only)



We established the basis for the determining the unknown risk factor applied within the TCD based on the above discussion, the AACE recommended practice note on accuracy range, and the observation of actual cost estimate changes in recent Australian transmission augmentation projects as they progressed through to advanced stages.

The AACE note RP 96R-18 defines typical accuracy ranges expected in power transmission line infrastructure project estimates as they transition from Class 5 to Class 1 and is shown in the following figure. The definition for this accuracy range in this context is that 80% of all past estimates fall within the upper and lower bounds. These accuracy ranges are useful simplifications for academic purposes, and only a starting point for determining the unknown risk in the TCD to compensate the accuracy offset observed in recent Australian transmission project cost estimates as they progress through to advanced stages.

Figure 9 Expected accuracy range – starting point

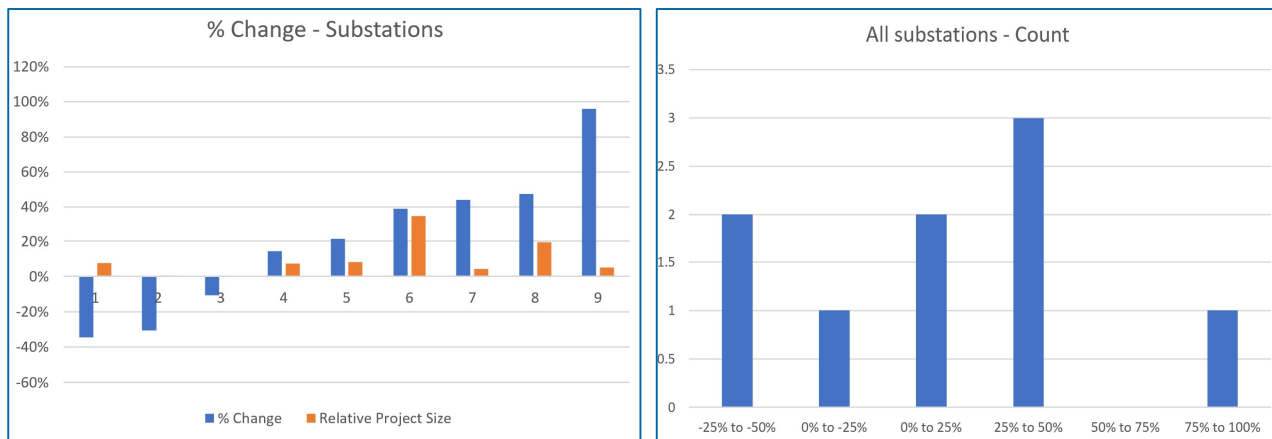


We have used this information as a starting position which has been further informed and refined from recent Australian transmission infrastructure augmentation project cost estimate data. The reasons and magnitude of changes from the Project Assessment Draft Report (PADR) to the CPA stage for these projects has been drawn upon to inform the determination of the unknown risk factors in the TCD. We note that this is mostly based on progressive updates to these recent project cost estimates, rather than actual or incurred cost records. In few instances some elements of these project estimates were based on newly executed contracts or competitive market bids. In the remainder of cases these project cost estimates were based on increasingly detailed or updated information.

We studied the progression of the total cost estimate of 22 recent major project network elements from early stage to advanced stage, focusing on the changing/increasing cost needed to correct the accuracy offset of early estimates compared to the later versions. The sample distribution also allowed a consideration of the estimate accuracy band. This consisted of 9 stations and 13 overhead line network elements. We acknowledge that the use of the cost estimate progression information for this purpose is presently a reasonable approach given the lack of major transmission augmentation project works in the NEM in recent history and thus the absence of actual cost information.

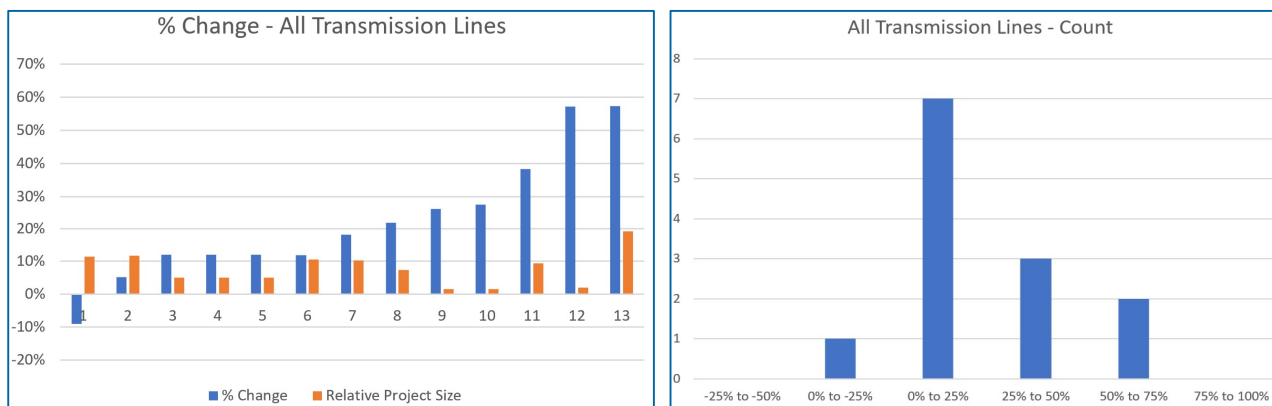
The following two graphs show the results of our study for the transmission station network elements. The blue bar in the left graph represents the magnitude of percentage change observed in the cost estimates between the PADR stage to CPA stage. The orange bar in the left graph represents the proportional or relative size of the station cost estimate with each other (i.e. together they constitute 100%). For example, the largest station is No. 6 and its cost estimate increased by ~40%. The histogram graph on the right shows the distribution of % change magnitude against the count of station network elements.

Figure 10 Recent Australian station network element cost estimates



The following two graphs show the result of our study for the transmission overhead line network elements. The blue bar in the left graph represents the magnitude of percentage change observed in the cost estimates between the PADR stage to CPA stage. The orange bar in the left graph represents the proportional or relative size of the overhead lines cost estimate with each other (i.e. together they constitute 100%). For example, the largest transmission overhead line is No. 13 and its cost estimate increased by ~55%. The histogram graph on the right shows the distribution of percentage change in magnitude against the count of transmission overhead line network elements.

Figure 11 Recent Australian overhead line network element cost estimates



Considering the above histogram graphs for both station and overhead line network elements, ignoring the outlier projects with extreme variations thereby capturing 90% of the network elements, and reviewing the causes of the variations, we observed the following:

- The accuracy range of the Australian TNSPs early stage (i.e. Class 5) cost estimate can be reasonably assumed to be $\pm 30\%$ based on the stated qualifications associated with most early stage cost estimates
- On average the Australian TNSPs changed/increased their early stage (i.e. Class 5) cost estimate by ~15%⁵. The change from Class 5 cost estimates were driven by the changes in all four unknown risk categories (scope and technology risks, productivity and labour cost risks, plant procurement risks, and

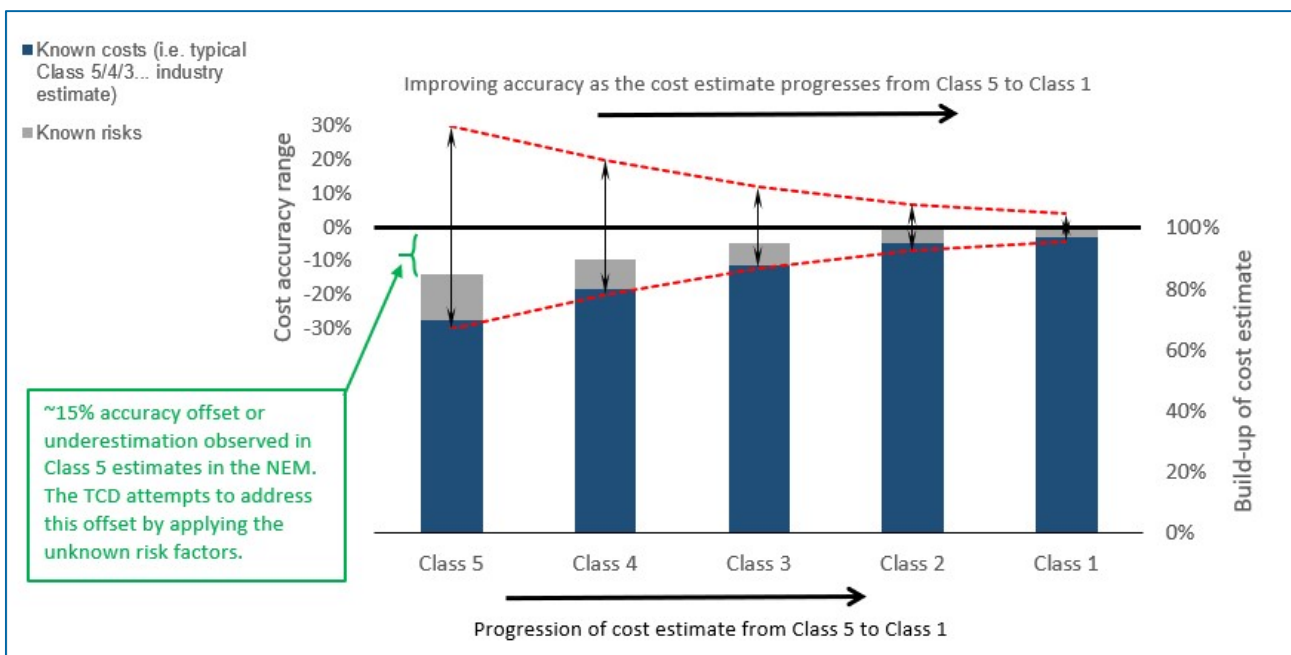
⁵ We observed the cost estimates increased approx. 12% to 18% (hence the average of ~15%). The increase to the station project cost estimates were towards the lower end of this range. The increase to the overhead line project cost estimates were towards the upper end of this range.

project overhead risks). The highest variations were due to scope increases (i.e. scope and technology risks)

- The larger variations in estimates were also driven by a mix of all 4 unknown risk factors.

The above three observations are summarised and illustrated in the following figure. In this chart the dark blue bar represents known costs (i.e. industry estimate commensurate with respective Class estimate). The grey bar represents known risk factors. The 0% cost accuracy axis represents the 'best estimate' of the final costs or the most accurate prediction and the red dotted line represents the improving cost accuracy range as the estimate progresses from Class 5 to Class 1.

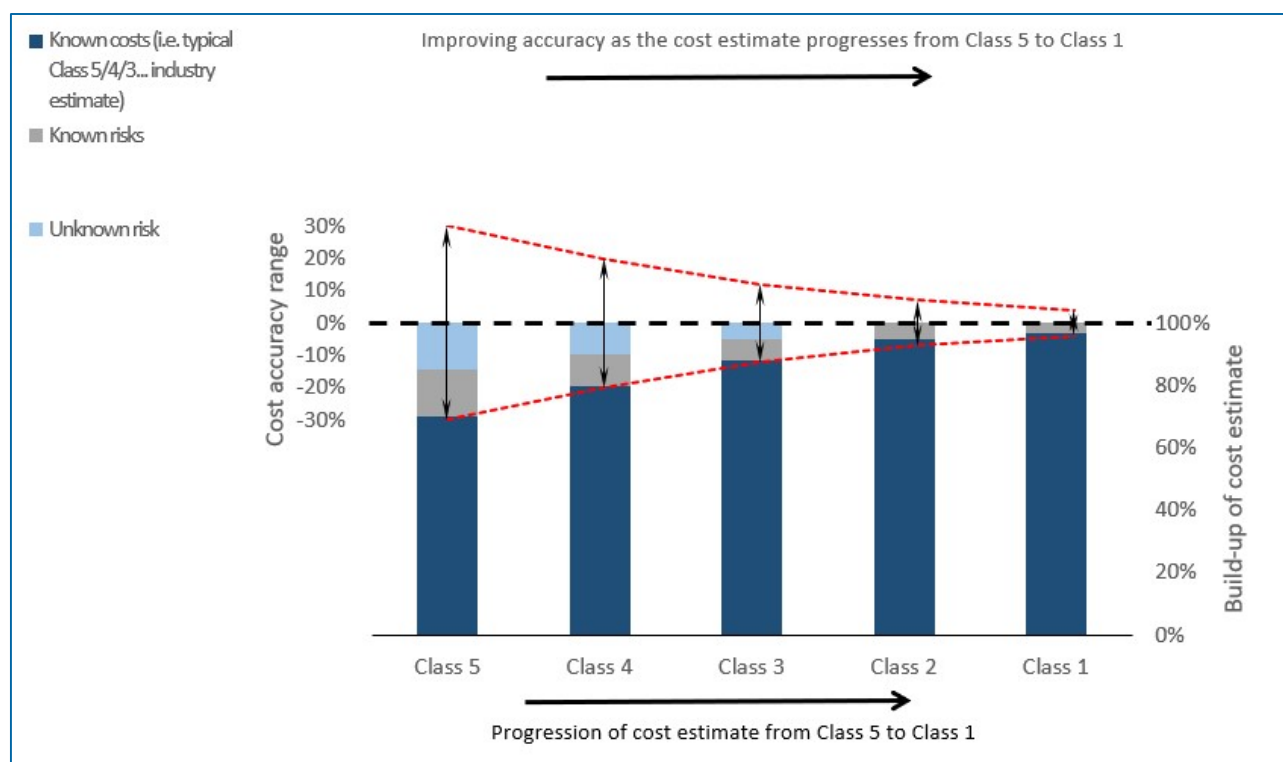
Figure 12 Recent class 5 estimates in NEM – accuracy range and offset/underestimation



A positive amount of contingency or unknown risk for all four unknown risk factors totalling ~15%, on average, would need to be added to the Class 5 cost estimate with known risks to reflect a 50% probability of underrun and overrun of the expected final project cost. This is an amount or factor needed in the estimate to deal with uncertainties inherent in the estimating process. Extrapolating this observation in a linear fashion, we note the total unknown risk factors of ~9%, on average, would need to be added to the Class 4 cost estimate with known risks to represent the 'best estimate'. Similarly, the total unknown risk factors of ~4%, on average, would need to be added to the Class 3 cost estimate with known risks to represent the 'best estimate'.

The application of this unknown risk factor to known costs (i.e. industry estimate commensurate with respective Class estimate) and known risks is illustrated in the following figure. In this chart the dark blue bar represents known costs, the grey bar represents known risk factors, and the light blue bar represents the unknown risk factors. The application of this unknown risk factors has brought the total expected cost estimate to the 0% cost accuracy axis representing the 'best estimate' of the final costs or the most accurate prediction. The red dotted line represents the improving cost accuracy range as the estimate progresses from Class 5 to Class 1.

Figure 13 Early stage cost estimate build-up proposed for TCD



In summary, the TCD has been designed to include a total unknown risk of ~15% for all Class 5 cost estimates, such that the total expected cost resulting from the TCD represents the 'best estimate' (i.e. on the 0% cost accuracy axis) and can be used as the midpoint of a symmetrical accuracy band for ISP modelling purposes. The accuracy of the Class 5 estimate produced in the TCD is $\pm 30\%$.

The equivalent total unknown risk factors for maturing classes of cost estimates are shown in the following table and is based on the discussion in earlier paragraph and also illustrated in the above figure with light blue bar. The associated accuracy range for the corresponding classes of cost estimates are also shown. It is noted that the improving accuracy range as the cost estimate matures have been formed based on linear extrapolation of recent NEM projects early stage cost estimate accuracy range and the AACE RP 96R-18 optimistic accuracy range for more advanced stage cost estimate (as shown in Figure 9). We note that this representation of improving accuracy range is mostly academic and based on observation of recent NEM projects as their cost estimates matured. Given the lack of major transmission augmentation project works in the NEM in recent history and thus the absence of empirical actual cost information allowing the estimate vs actual cost analysis (with benefit of hindsight), further conclusive insight into the improving accuracy range is unavailable. As such the data in the following table should be viewed in this context.

Table 8 Total unknown risk factors, on average, at different cost estimate classes and associated accuracy range

Cost estimates	Class 5	Class 4	Class 3	Class 2	Class 1
Total unknown risk factor	~15%	~9%	~4%	0%	0%
Accuracy range	$\pm 30\%$	$\pm 20\%$	$\pm 15\%$	$\pm 10\%$	$\pm 5\%$

In the future as the major transmission augmentation projects are delivered and completed in the NEM, this analysis should be revisited based on comparison of cost estimates with actual incurred costs.

Presently the TCD is designed to only produce early stage (Class 5/4) project cost estimates. While the TCD contains unknown risk factors for advanced stage cost estimate (i.e. Class 3/2/1), such factors are only to be used by AEMO to review advanced stage cost estimates provided by the project proponents.

We consider this a reasonable approach to allocating a contingency for unknown risk. This is a judgement-based approach of including and modifying contingency for unknown risks. The expectation is that unknown risks will reduce to near zero as the project advances to delivery.

8.5 Indirect costs

Indirect costs are applied after all the network elements of the project are estimated with their respective project attribute and risk factors. Indirect costs are applied to the total network element costs considering economies of scale and are dependent on the overall project attribute choices of green/brownfield nature, stakeholder engagement level and contract delivery model. The indirect costs are estimated using a 'top-down' percentage of project cost and are driven by these dependent variables. The selection for the dependent variables is either given (for total network element cost) or user input choices representing a summary of all network elements. In other words, the choices of overall project attribute should reflect the majority of the project, even though the individual network element may differ (for e.g. one brownfield network element in a mostly greenfield project).

The percentage for the indirect cost and its breakdown component factors is derived based on GHD's project owner cost model and benchmarked against recent transmission projects in the NEM. It is also based on our understanding on other infrastructure project owner costs, international experience and knowledge of how the business units and various functions within TNSPs in the NEM are generally structured and the nature of activities carried out to develop and deliver projects across the business.

It represents the owner internal costs to identify the need for the project, preliminary investigations, option analysis, project development, procurement, contract management, administration and insurance. The total indirect cost ranges from ~6.5% to 16% of the total network element cost and is broken down into 6 cost descriptions to match with the usual internal costs observed by TNSPs.

9. Benchmarking

9.1 Calibration

As explained in section 7 of this report, we identified a number of major transmission augmentation projects that are currently being developed across different NEM jurisdictions and also across different stages of cost estimation (from Project Specification Consultation Report (PSCR) to CPA stage).

We had access to the cost estimate of 4 major projects with a diverse mix of various network elements, voltage levels, locations and estimate classes. All of this information has been treated with due care to maintain its confidentiality. We note that some of this information is publicly available in the AER website included within RIT-T and CPA submissions and review process documentation.

For the purpose of testing the output of the TCD, we referred to these TNSPs cost estimates as appropriate benchmarks as they have been prepared by industry experts following their respective organisation established processes and with much greater ability to 'sound out' or test the market for prices. This allowed us to test and calibrate wide range of variables data contained within the Cost and Risk Data workbook and the calculation logic used in the cost estimation tool.

The benchmarking prompted us to focus and revise (reduce) the allocation of unknown risk factors to match the accuracy offset margin observed across multiple recent NEM network project cost estimates as they developed into mature estimates as described in section 8.4. The earlier version of the Cost and Risk Data workbook contained generic/placeholder values.

The TCD building block unit rates when benchmarked against the provided TNSP project estimates is directly compared irrespective of the project scope refinement status as defined by the TNSP estimate Class definition. To undertake this unit rate calibration we compiled the project estimate in the TCD replicating the TNSP project description, scope and other input variables, minus any contingency contained in the provided TNSP estimate. We applied the Class 3 unknown risk factors irrespective of project estimate Class scope definition so as to make comparisons based on unit costs only. We carefully considered the inclusions and exclusions contained in the provided TNSP project estimate so that the benchmarking against the TCD generated estimate were under the same basis. The $\pm\%$ variation observed in each network element between the two sets of project estimates indicated the degree of calibration ($\pm\%$ adjustment) needed in the TCD building block unit rates contained within those network elements.

We performed this benchmarking in the same fashion against every provided TNSP project estimates and observed the $\pm\%$ adjustment needed in the TCD building block unit rates. In case of multiple observations for the same category of building block unit rates, we gave more weighting or preference to those $\pm\%$ adjustment resulting from more mature Class of estimates. In other words, $\pm\%$ adjustment observed from benchmarking with Class 3 estimate defined by TNSP were preferred over $\pm\%$ adjustment observed from benchmarking with Class 5 estimate defined by TNSP (based on the assumption that unit costs in a Class 3 estimate should be more accurate than in a Class 5 estimate).

This resulted in the calibration of the following variables in the Cost and Risk Data workbook:

- Building block unit rates for transformer, reactor and phase shifting transformers sub-categories were reduced to extract out element of risks embedded into them and avoid double counting when risk factors are applied to build the total cost
- Building block unit rates of the entire overhead lines category were corrected to allow for various specific types of conductor. The overhead line category unit rates were initially adjusted to correct the calculation apportioning the fixed mobilisation cost to 'per km' cost. These were subsequently increased based on the % adjustment needed in these TCD building block unit rates as explained above.

The benchmarking against the 4 provided TNSP project estimates was an iterative process that resulted in the above calibration. We also corrected data entry errors in few instances in such iterative runs, with the TCD output finally indicating a much closer alignment universally across the diverse network elements.

9.2 Comparative estimate

Following on from testing the cost estimation tool calculation logic and the Cost and Risk Data workbook variables, especially the building block unit rates calibration, we performed comparative estimates of the provided TNSP projects. We performed this by using the TCD and applying the appropriate unknown risk factor (for both scope and cost components) commensurate with the provided project estimate Class definition with an aim to produce the 'best estimate' whether or not the TNSP estimate included contingency.

To undertake this comparative estimate we first assessed the appropriate project estimate Class definition applicable for unknown risk factor for both scope and cost components. We considered the TNSP claimed estimate Class definition and independently assessed them against publically available information on those projects such as description of work and route distances in aerial map. We then formed a view regarding the

unknown scope and cost risk factor Class definition for each provided TNSP project estimates and applied them to generate the 'best estimate'.

For example, if the provided TNSP estimate was deemed to meet the criteria of Class 3 definition for both unknown scope and cost risk factors, then Class 3 was selected for both unknown scope and cost risk factors as both those variables were regarded to be refined and more definitive. Similarly, if the provided TNSP estimate was deemed to meet the criteria of Class 3 definition for unknown cost risk factor but Class 5 definition for unknown scope risk factor, then Class 3 and Class 5 were respectively selected for unknown cost and scope risk factors as only one variable was regarded to be refined and definitive.

We also carefully studied the inclusion/exclusion of specific cost items/components such as indirect costs and property acquisition costs in the provided TNSP project estimates so that the costs were appropriately compared.

The high-level summary of each of the 4 project cost estimates are as follows:

- Project 1 estimate consisted of 4 network elements, including station and overhead line categories, and voltage level from 220kV to 500kV. Both the unknown cost and scope risk factors were deemed to meet the criteria of Class 4 definition
- Project 2 estimate consisted of 4 network elements, including station and overhead line categories, and voltage level from 220kV to 500kV. The unknown cost risk factors were deemed to meet the criteria of Class 3 definition and the unknown scope risk factor was deemed to meet the criteria of Class 5 definition
- Project 3 estimate consisted of 5 network elements, including station and overhead line categories, and voltage level from 330kV to 500kV. Both the unknown cost and scope risk factors were deemed to meet the criteria of Class 3 definition
- Project 4 estimate consisted of 3 network elements, including converter station and overhead HVDC line categories, at ± 500 kV. Both the unknown cost and scope risk factors were deemed to meet the criteria of Class 5 definition.

These project network elements contained a diversity of capital works, characteristics (i.e. selection of various project attribute factors), and risk exposure (i.e. selection of various risk factors). The majority (i.e. 14 of the total 16 network elements) of the TCD outputs or comparative estimates are within $\pm 15\%$ of the provided TNSP project estimates. This positioning provides reasonable confidence that the cost estimates generated by the TCD is in alignment with the industry reference, provided the inputs are objectively entered/selected.

The summary of these comparative estimate results, at each iterative run after the revision of the Cost and Risk Data workbook and changes/corrections to input data, has been provided to AEMO in a confidential appendix. In addition to the summary tables, reports of these benchmarking activities were provided to AEMO in 4 separate and respective excel files showing the benchmark project scope and qualification input data and the TCD generated output or comparative estimate against the provided TNSP project estimate.

10. Qualification and application of TCD estimates

Given the characteristic and basis of the underlying variables, as explained in section 8, that constitute the Cost and Risk Data workbook, the TCD generated cost estimate is made up of the following:

- Selection of a number of building blocks which are described at a fairly high level (for e.g. \$/km of underground cable infrastructure, instead of dollar per every individual cost item that constitute the underground cable infrastructure). Diligent care has been taken to document such unit rates at Class 5/4 cost estimate level and to not include any risk costs that are explicitly accounted for in the intended use of the TCD
- The cost estimate for these building blocks or baseline are adjusted based on specific characteristics or attributes of the network elements as selected by the user
- Known risk allowances are added to the adjusted baseline cost to match the project risk exposure as considered by the user for each network element
- Unknown risk allowances are added to the adjusted baseline cost to compensate for the accuracy offset commensurate with early stage costs recently observed in NEM transmission project estimates
- Indirect costs are then added to the sum of all network element cost estimates which are inclusive of their respective project attribute and risk adjustment factors based on the nature of the overall project.

We note that as the project cost estimate matures to an advanced stage (i.e. Class 3/2), the accuracy range narrows (i.e. estimate becomes more definitive) as many uncertainties from the early stage become known and can either be defined as a new scope of work or new set of building block or contracted to the party best able to handle it. Advanced stage estimates need new sets of building block unit rates commensurate with Class 3/2 estimate which captures appropriate and bespoke level of details and includes cost to own and manage identified risks. Such a new set of building block unit rates also needs to be treated with new and definitive sets of quantity inputs. Accordingly, a new set of building block costs needs to be treated with refreshed adjustment factors that may not have been previously incorporated in the new building block unit rates.

We note the TCD is presently set-up with inputs to produce Class 5/4 cost estimate only. The user needs to diligently input and choose their selections in the TCD accordingly. As the project development matures to advanced stage, the dark blue area of the bar chart in Figure 13 representing known cost (i.e. quantities × unit rates) increases, while the grey and light blue areas of the bar chart representing uncertainty decreases.

Provided the inputs to the TCD are carefully entered and the variable choices diligently selected so that they are compatible with the intended use of the TCD, the generated cost estimate comes with the following qualifications:

- The output is a Class 5/4 estimate and therefore suitable for early stage of project development
- The output is a point estimate calculated in a deterministic or parametric fashion. In other words, it is not a 'P-' estimate and does not have any associated statistical qualification (confidence level, probability distribution functions, standard deviation etc.). No stochastic simulation was involved in the TCD cost estimation
- The output has ±30% accuracy range (based on a sample of past Class 5 transmission network estimates)
- The output is the 'best estimate' with an aim of being equally under and over the expected costs in an advance cost estimate. The early stage cost estimate output aims to align itself closely to the 0% cost accuracy axis
- The output should be applied as a point estimate with the above qualifications for the ISP modelling purpose
- The building block costs are in real 2021 Australian dollar values. Therefore, the output is in 2021 Australian dollars

- The output represents Australian construction environment, asset and design standards, industry and business practices, regulatory framework, commercial rules, labour laws and safety regulations in 2021
- The output represents stable macroeconomic (forex, commodity, labour and wage price indices), social and political conditions that Australia has experienced in recent years up to 2021
- The output represents efficient preliminary investigation, project development, project management, competitive tendering, site management and contractual arrangements.

11. Future development

As with any business tool and underlying information that feeds the tool, this newly developed TCD should be maintained and periodically reviewed for fitness of purpose. Given the ever-changing nature of cost with time (i.e. nominal value of dollar), AEMO needs to regularly update or refresh the cost estimate inputs in the TCD. This may involve escalation of cost inputs with passage of time using the readily available economic indicators such as CPI and WPI trends available from recognised source such as ABS at determined frequency.

We note that such approach to match the inflation trend is reasonable only for a relatively short period (for e.g. 10 years), after which it is recommended to test the market to obtain new set of cost information. Such a decision should be made based on the market movement of the cost observed by the industry.

We understand that AEMO aims to update the TCD when real projects are completed by reviewing, and if necessary, updating the building block unit rates and the attribute and risk factors through new rounds of benchmarking process. We also understand that through this mechanism, AEMO aims to build up a database of completed project costs over time, which will allow improvement in the cost estimate generated by the TCD.

In order to maintain the validity of the TCD and its cost estimate output, it is recommended that AEMO pay attention to the following industry triggers to review the fitness of the TCD and decide on refreshing it:

- New actual project costs become available, post project delivery
- Substantial regulatory and market changes
- Substantial changes to labour law
- Substantial changes to traditional Australian and overseas supply chain
- Substantial technology changes that introduce new types of asset, requirement of new/different knowledge and skill sets
- Substantial changes to a number of Australian design standards, asset specifications and safety requirements.

Finally, we note the following potential upgrades to the TCD in the future:

- Addition of new set of unit rates for the existing building blocks commensurate with advanced stage (i.e. Class 3/2) estimates enabling users to perform advanced stage cost estimates. This will require corresponding refreshing/removing of project attribute and risk factors. This will also result in an extensive library of unit rates each with bespoke scope of work
- Disaggregate the existing building block description into granular cost items to allow formulating bespoke combination of assets and scope of work. This is risky as the TCD may become less user

friendly, unwieldy and cumbersome to maintain. This is a trade-off between output accuracy and input effort requirement

- Conversion of generated cost estimate in real dollar term to forward looking cost estimate in nominal dollar term for any given future year using the forecast of appropriate escalation indices. This will require procuring such forecast indices from the market. It is noted that the 'shelf life' or validity of such forecast indices are very short, and their forecast time horizon are usually limited to 6-24 months into the future
- Based on the continuous use of the newly developed TCD and feedback from various users, add new functionalities to increase user friendliness, ease of administration/housekeeping, and/or address issues that may arise at later date
- Transfer the TCD from Excel platform to more conducive platform (such as Access Database or similar) to optimise the existing algorithm in the cost estimation tool and to add new functions.

Appendices

Appendix A Abbreviation

The following acronyms, listed in alphabetical order, have been used in the TCD, throughout this report, and in the user and custodian manuals (see Appendix C and Appendix D). The users are expected to know them before proceeding to compile their cost estimates using the TCD.

- AACE = The legal corporate name of this organization is AACE INTERNATIONAL, INC., hereinafter referred to as 'AACE'. AACE previously referred to the Association for the Advancement of Cost Engineering International. It was chartered in 1956 as the American Association of Cost Engineers.
- ABS = Australian Bureau of Statistics
- AEMO = Australian Energy Market Operator
- AER = Australian Energy Regulator
- AIS = Air Insulated Switchgear
- BAU = Business As Usual
- CB = Circuit Breaker
- CPA = Contingent Project Application
- CPI = Consumer Price Index
- CT = Current Transformer
- CVT = Capacitive Voltage Transformer
- DCST = Double Circuit Single Tower
- EPC = Engineering, Procurement and Construction
- EPCM = Engineering, Procurement, Construction and Management
- ES = Earth Switch
- GIS = Gas Insulated Switchgear
- HTLS = High Temperature Low Sag
- HVAC = High Voltage Alternating Current
- HVDC = High Voltage Direct Current
- ISP = Integrated System Plan
- LCC = Line Commutate Converter. A type of HVDC converter based on thyristor technology
- NEM = National Electricity Market (consisting of jurisdictions of Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia and Tasmania)
- OEM = Original Equipment Manufacturer
- PACR = Project Assessment Conclusions Report. The third and final milestone and a part of the RIT-T process
- PADR = Project Assessment Draft Report. The second milestone and a part of the RIT-T process
- PSCR = Project Specification Consultation Report. The first milestone and a part of the RIT-T process
- PTRM = Post Tax Revenue Model

- REZ = Renewable Energy Zone
- RIT-T = Regulatory Investment Test for Transmission
- ROI = Remotely Operated Isolator (motorised isolator or disconnecter)
- SA = Surge Arrestor
- SCST = Single Circuit Single Tower
- SVC = Static Var Compensator
- TCD = Transmission Cost Database
- TNSP = Transmission Network Service Provider
- Tx = Transformer
- VSC = Voltage Sourced Converter. A type of HVDC converter based on transistor technology
- WPI = Wage Price Index

Appendix B Glossary

The following phrases and terms, listed in logical order of reference, have been used in the TCD, throughout this report, and in the user and custodian manuals (see Appendix C and Appendix D). The users are expected to know them before proceeding to compile their cost estimates using the TCD.

- **Functional Specification:** A 'road map' document describing the structure and components of the TCD, inputs requirement and outputs displays, model interfaces, cost build-up approach using the building blocks and various adjustment factors to calculate the total expected cost for the project.
- **Cost and Risk Data workbook:** An Excel file populated with the underlying building block unit costs, project attribute factors, risk factors, and indirect cost factors data, along with source/basis information. Together with the cost estimation tool, it constitutes the TCD.
- **Cost estimation tool:** An Excel file that allows users to build up a project cost estimate based on the information contained within the Cost & Risk Data workbook using with interactive 'Dashboard' containing algorithms that processes the user inputs and selection choices. The algorithms are written using VBA programming language and macro codes. Together with the Cost and Risk Data workbook, it constitutes the TCD. It also contains a copy of the Cost and Risk Data workbook file and is published for AEMO and stakeholder use.
- **Network Element:** Unique and discrete parts of the given capital project consisting of distinctive scope of work, geographical location and condition, construction method, knowledge discipline and expertise, and asset types. Project can be disaggregated into multiple distinctive parts depending on their unique attributes and risk characteristics. Each such distinctive part is termed as 'network element' of the project. A project may consist of one or multiple network elements.
- **Building block:** Unique and discrete set of capital assets that describes a logical group or block of transmission network infrastructure elements. Each building block may consist of several individual asset items configured and grouped in a certain/standard manner. For e.g. an overhead transmission line building block consists of towers, foundations, conductors, insulators, fittings etc. The building block just by itself does not work or is meaningless in isolation. It needs other building blocks (i.e. connected and configured to each other in a logical and specified manner) to operate and function as intended. For e.g. the overhead transmission line building block needs to terminate at the ends and therefore will need switchbays at the terminating stations.
- **Adjustment factors:** Collectively used term to describe the following three factors that modifies or adjusts the building block or baseline cost estimate to match the project specific characteristics and risk profiles:
 - Project attributes
 - Known risks
 - Unknown risks.
- **Project attributes:** Various descriptions (such as geography, project size, contracting model etc.) that describe the nature of the project network element specifically to modify the building block cost estimate to match the characteristics.
- **Known risks:** Risks that are evident at the time of developing an estimate. It consists of known uncertainty in scope and costs for the project and also includes delivery related risks (e.g. wet weather delays). Known uncertainty will be priced in by the contractors and service providers during the tender

stage as the project develops and progresses through to the final approval. The residual delivery related risk is expected to continue to remain with the project proponent.

- **Unknown risks:** Also known as 'contingency' and by definition cannot be defined. However, empirical experience post capital infrastructure projects and with benefit of hindsight suggest that cost estimates prior to such project commencing usually fail to capture the entire costs involved in its delivery. Based on empirical observation AACE recommends classifying cost estimates according to various maturing stages of scope definition and prescribes inclusion of unknown risk or 'contingency' in the estimate to achieve the expected accuracy range respectively at each stage. The cost estimator needs to objectively identify maturity of the project scope definition and use the best judgment at the time of estimation to include unknown risks in the estimate.
- **Category:** The highest or first level categorisation of asset building block (into station, overhead line and underground cable) and their corresponding grouping of adjustment factors (i.e. project attributes, known risks and unknown risks). A category is made up of multiple sub-categories.
- **Sub-category:** The next or second level categorisation of asset building block within each category. In the case of adjustment factors, the varieties of factor and choices available within each adjustment type.
- **Baseline cost:** Sum of building block estimates compiled for a given scope of work.
- **Adjusted baseline cost:** Baseline cost modified or adjusted by applying the specific project attribute factors for the given scope of work.
- **Total network element cost:** Adjusted baseline cost + known and unknown risk allowance for the given scope of work.
- **Indirect costs:** Owners internal costs incurred in identifying the need for the project, preliminary investigation, developing the project, preparing for regulatory approvals, establishing procurement arrangements, and securing insurances.
- **Total expected project cost:** Sum of all network elements total costs which have been respectively adjusted based on specific project attributes and risk profiles and inclusive of the indirect costs, i.e. Total network element cost + Indirect costs
- **Estimate class:** Classification of cost estimate type ranging from Class 5 (early stage estimate with minimal information) to Class 1 (most definitive estimate with detailed specification of work and locked contracts) as per the AACE guideline.
- **Switchbay:** A predefined configuration of various switchgear (circuit breaker, current transformer, capacitive voltage transformer, surge arrestor, earth switch etc.), civil and structural assets (busbar, gantry, trenching), and secondary system (relays, control panel) according to standard design and industry practice that protect major transmission infrastructure elements (transformers, overhead lines, reactive plants etc.) from abnormal conditions. It also measures and facilitates monitoring the operational and performance parameters of such elements. It can be situated in the switchyard (AIS/outdoor) or housed within the building (GIS/indoor).
- **Diameter:** A predefined configuration of one or multiple switchbays according to standard design and industry practice such as 'breaker and half' configuration where three switchbays protect, measure and monitor two major transmission infrastructure elements.

Appendix C User Manual

C.1 User Prerequisites

A user of this tool should be aware of the assumed prerequisites necessary to develop a cost estimate with this tool. It is expected that the user of the TCD be well versed with the electricity transmission network industry in Australia, especially the NEM. The user:

- Should be familiar with various assets types and the capital project development and delivery of such assets that forms the electricity transmission network infrastructure
- Should have general knowledge of industry practices and standards with respect to asset description and specifications, procurement arrangements, network design, regulatory approval processes, construction management and safety protocols
- Does not need to be an expert in all these areas but is expected to have access to resources to inform the use of the TCD and be fully aware of topics discussed above
- Has carried out professional work experience in the industry such that they would meet the prerequisites outlined above.

The user's approach must consider a range of input information which defines the project scope and determines the maturity of the project. The user of the TCD should define or have access to the scope of work in order to build the cost estimate. The information outlined in the scope should be objective and without bias to choose appropriate risk exposure and network element components known at the time of building the cost estimate. Useful sources of information the user can rely on include:

- Preliminary investigation, option and scoping reports (internal business documentations)
- Work briefs
- Single line diagrams which depict the project design
- General arrangement diagrams
- TNSP station building standards, Australian Standards
- Asset specifications (size, fault level, maximum demand)
- Access route map (desktop analysis)
- Preliminary environmental investigation
- Any other information available.

As the project development matures and advances through to final investment approval gates, such information will be re-evaluated and will also be supplemented by further project information. Re-evaluation of the project scope is dynamic and ongoing from a preliminary cost estimate all the way to the final cost estimate and it is the responsibility of the TCD user to conduct these regular updates.

Use of the TCD is not recommended if the user has advanced and definitive project scope details that can identify and easily itemise comprehensive scope of work at bespoke and granular level, such as for Class 3, 2 or 1 stages. In this case, the cost estimate should be built up using dedicated cost estimation software and a comprehensive risk analysis approach, including expert peer review.

C.2 Breaking down project into multiple network elements

A project and its overall cost estimate can be disaggregated into multiple distinctive cost estimates grouped by their attributes and risk characteristics. Each distinctive grouping is a unique 'network element' and a project is made up of multiple network elements. A network element is a group of transmission elements (building blocks) which share identical project attributes and risk. At a minimum, and if applicable, a project is disaggregated into the following network elements:

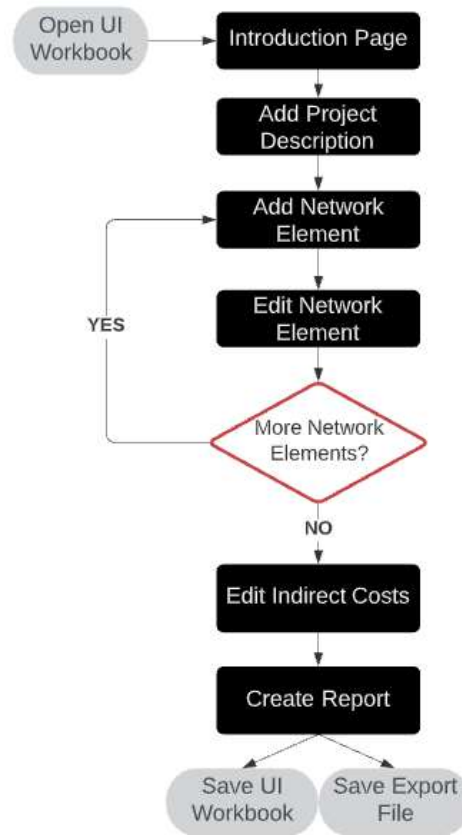
- Stations
- Overhead lines
- Underground cables.

Determination of a network element's attribute and risk is based on the scope of work of the project and the unique characteristics of that particular group of building blocks. For example, a network element which defines a station may contain a number of building blocks, such as switchbays and transformers, which share common attributes (Contract Delivery Model) and risks (Environmental Offset Risks). Stations which do not share the same site should be treated as separate network elements. Additionally, an overhead transmission line can traverse more than one terrain type or jurisdiction. Multiple network elements would be required to estimate the full length of the transmission line. Typically, maturation of a project scope would result in re-evaluation of the number of network elements necessary to develop a project cost estimate. The more defined a project scope is the more likely the user may choose to disaggregate network elements into more, smaller elements. Disaggregating a project into network elements is an accuracy vs effort trade-off exercise.

C.3 Cost estimation tool workflow

The cost estimation tool follows a structured workflow which guides the user from opening the cost estimation tool to generating a project cost estimate. It is critical that the user follows the cost estimation tool's intended workflow to ensure that the project cost estimate is fit for purpose. Figure 14 illustrates an overview of the intended cost estimation tool workflow as a flowchart.

Figure 14 Cost estimation tool workflow



The stages within the black boxes of the cost estimation tool flowchart require user interaction. The following section will provide detailed user instructions for each stage to generate a project cost estimate using the cost estimation tool.

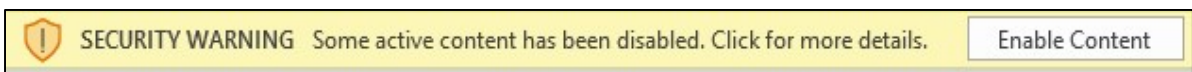
C.4 Step-by-step cost estimation tool guide

C.4.1 Step 1: Introduction page

1. Enable content

Upon opening the cost estimation tool, an Excel security warning popup will appear as shown in Figure 15.

Figure 15 Security warning for enabling macros



It is critical that the user enables content to allow the macros to function. This warning popup may appear repeatedly after closing and reopening the file – please enable each time.

Note: The security warning popup may look different depending on the MS Excel version of the user. Please read the message to ensure that content/macros are enabled.

2. Read introduction page message

After enabling macros, the cost estimation tool will take the user to the *Intro* tab. The page details important information regarding the TCD including the purpose, disclaimer and copyright statement.

3. Start project

Note that at any point in this process, the user can save the file and return to it later to complete.

To start building a project, click on the *Start Project* button as shown in Figure 16 below.

Figure 16 Introduction page

Transmission Cost Database

IMPORTANT NOTICE

Purpose

AEMO has made the transmission cost database available as a companion resource to the Integrated System Plan (ISP) published under the National Electricity Rules. The database will be used by AEMO for estimating transmission costs and reviewing estimates received from TNSPs. The purpose of its publication is to increase transparency of the inputs used by AEMO to evaluate ISP network projects, and it is intended for an experienced audience. Use of the transmission cost database requires a highly developed understanding of the National Electricity Market power system and industry.

The database should be used in conjunction with the ISP Transmission Cost Database Report, to explain the assumptions, inputs and methodology underlying the database build, and the most recent version of the Transmission Cost Database User Manual, to explain how the database is used to estimate transmission costs. Please refer to the most up to date version of the ISP Inputs, Assumptions and Scenarios Report for details of ISP projects whose costs have been estimated by AEMO using this database.

Disclaimer

The database is only current as at the stated version date, and the information in it may change subsequently.

The database includes collated information and estimates from third parties and public reports based on a range of data for past and current network projects. The database output is considered high level only, commensurate with conceptual projects, and is not suitable for use in more advanced project stages where detailed design information is available. AEMO has sought to ensure the quality of the information, but the database may not be accurate or complete, and does not include all of the information that an investor, participant or potential participant in the National Electricity Market might require. You should always obtain advice from suitably qualified experts in relation to your specific circumstances, and on the use and interpretation of results from the database.

Accordingly, to the maximum extent permitted by law, AEMO and its officers, employees and consultants involved in the preparation of the transmission cost database and estimating tool:

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the database contents or outputs;
- are not liable (whether by reason of negligence or otherwise) for any estimates, forecasts, opinions or other matters contained in or derived from the contents of the database, or any omissions from it, or in respect of a person's use of the database.

Copyright

© 2021 Australian Energy Market Operator Limited. The material in this publication may be used in accordance with the copyright permissions on AEMO's website.

Start Project

Clicking the *Start Project* button will take the user to the project main screen shown in Figure 17 below.

Figure 17 Cost estimation tool main screen

Project Main Screen

1

Add Project Description

Name

Description

Display Cost and Risk Data

Data Source:

AEMO TCDB Cost and Risk Data

Data Source Date:

16 March 2021

2

+ Add

Duplicate

Remove

Edit

List of Network Elements

Network Element Number	Network Element Name	Description

3

Select Network Element to Add Components

Please Click a Network Element from List of Network Elements

Edit Network Element >>>

4

Set Indirect Cost Choice

Edit Indirect Costs >>>

5

Export Project Cost Summary

Create Report

Reset Project

On the project main screen, each section is numbered to help the user navigate the cost estimation tool in creating a project cost estimate.

C.4.2 Step 2: Describe your project

1. Add project description

Click on *Add Project Description* to assign a name and description for the overall project. A user form will appear for the user to input the project name and description, as shown in Figure 18 below.

Figure 18 Adding project description

Click *Proceed* after filling out the name and description fields. The user can clear the current inputs by pressing the *Reset* button. To edit the name and description at a later point, click *Add Project Description* and make amendments. *Note: the project name and description will appear on the generated output reports.*

C.4.3 Step 3: Describe each network elements within the project

1. Add network element

Click *Add* to add a new network element. Two input boxes will appear one after the other, requiring the user to input the network element name and description. Enter an appropriate name and press *OK* – repeat for description. An example is shown in Figure 19 below.

Figure 19 Adding network elements

After completing the input boxes, the user's entry will appear in the table *List of Network Elements* and a network element number will be assigned.

Figure 20 Table of network elements added

 Add

 Duplicate

 Remove

 Edit

List of Network Elements

Network Element Number	Network Element Name	Description
1	Overhead Line 1 (Example)	500kV DCST - 100km (Example Description)
2	Example Name 2 --> Description blank	

Note: a name must be assigned when adding a network element, however the description can be left blank.

The user has the option to add all network elements at this stage. Alternatively, the user can progressively add and edit network elements. It is suggested that the user complete all entries for the first network element, this is particularly important if the user plans to employ the duplicate functionality discussed below.

2. Duplicate network element

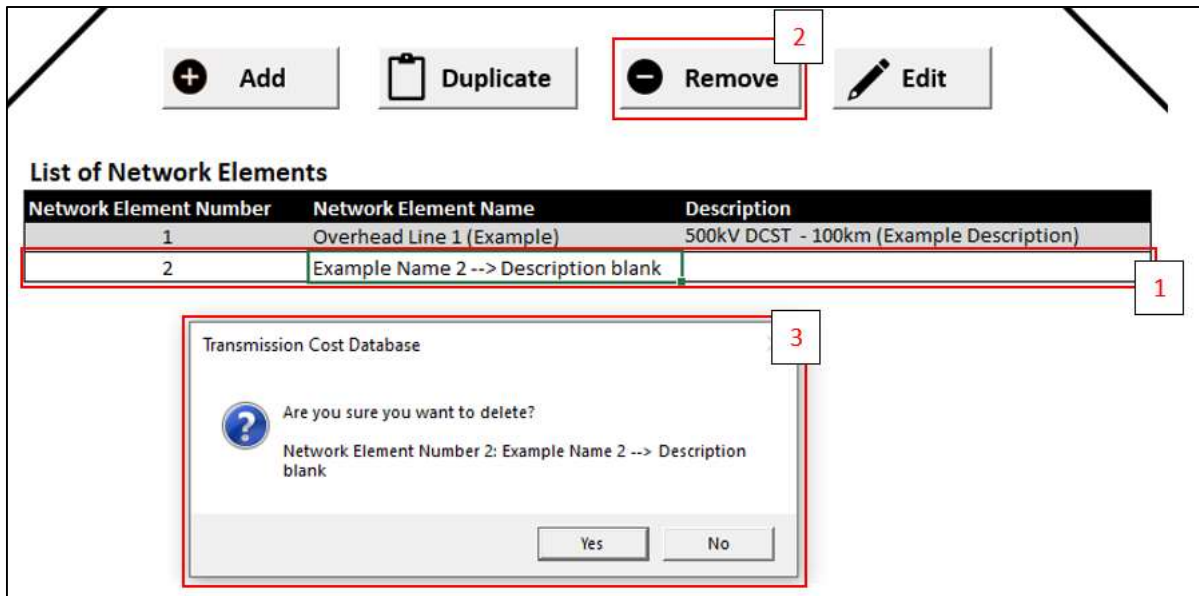
The duplicate functionality of the cost estimation tool allows the user to replicate an existing network element entry and its associated entries assigned by the user in *Step 4: Edit Network Element*. This functionality is useful in cases where the user has one or more network elements that have largely similar inputs. Instead of adding and editing an entire network element again, the user can duplicate an existing network element and make small amendments to the duplicated network element.

Select the network element to be duplicated by clicking on the corresponding row within the table *List of Network Elements* (can be any column). After selecting the network element, click on *Duplicate*. Two input boxes will appear similar to that of the *Add* functionality. The user will be required to assign a name and description to the new network element.

3. Delete network element

Select the network element to be deleted by clicking on the corresponding row within the table *List of Network Elements* (can be any column). After selecting the network element, click on *Remove*. A confirmation warning will appear before deleting the network element. Confirm the appropriate network element has been selected and click *Yes* to proceed with the deletion. If the user made the wrong selection or no longer wishes to delete the network element, click *No* to cancel.

Figure 21 Removing network elements



The network element and all user inputs that had been assigned to this network element number in *Step 4: Edit Network Element* will be permanently deleted. The user must be cautious when removing network elements, as the cost estimation tool cannot recover the network element and associated entries once deleted.

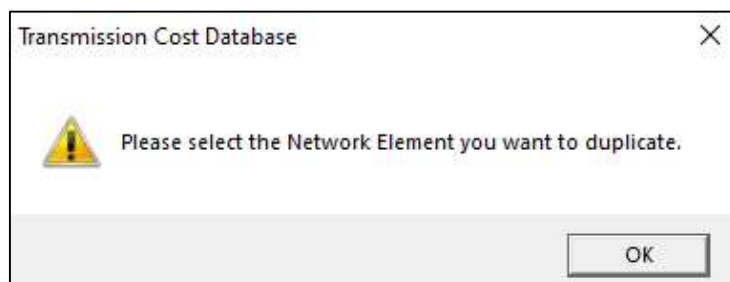
4. Edit network element

Select the network element to be edited by clicking on the corresponding row within the table *List of Network Elements* (can be any column). After selecting the network element, click on *Edit*. The input boxes from the *Add* button will appear. Make changes to the name and description and press *OK*. The changes will be updated within the *List of Network Elements*.

5. Tips / caution

For the *Duplicate*, *Remove* and *Edit* buttons, an error will occur if the user has not selected an appropriate cell within the *List of Network Elements*. The error message can be seen in Figure 22 below.

Figure 22 Invalid cell selection warning



In the example below using three network elements, to duplicate/remove/edit the user must click on any of the yellow cells Network Element 1 (blue cells for Network Element 2 and green for Network Element 3). Any other cell selection will lead to the above error. Press *OK* on the error message to proceed and click the appropriate cell before using the duplicate/remove/edit functionalities.

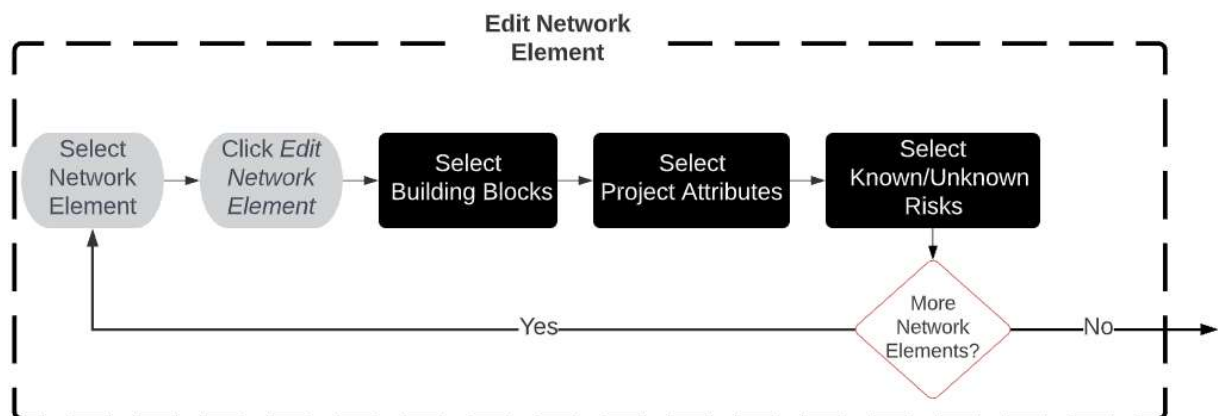
Figure 23 Example of valid and invalid cell selections

Network Element Number	Network Element Name	Description	
1	Overhead Line 1 (Example)	500kV DCST - 100km (Example Description)	✓
2	Example 2		✓
3	Example 3		✓

C.4.4 Step 4: Edit network element

Step 4 involves choosing the appropriate building blocks that forms the network element, inputting the quantities, selecting project attributes and risk factors for the nominated network element in the table *List of Network Elements*. This step will guide the user through different screens for each assignment. The workflow of this stage can be seen in Figure 24 below.

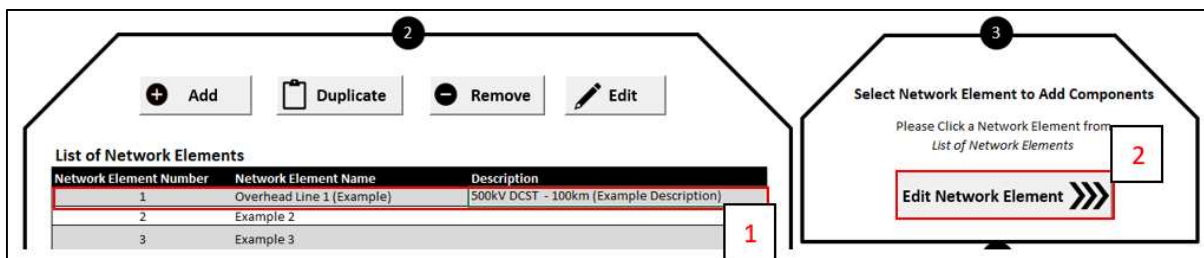
Figure 24 Editing network elements flowchart



1. Select network element to edit

Select the network element to be edited by clicking on the corresponding row within the table *List of Network Elements* (can be any column). After selecting the network element, click on *Edit Network Element*.

Figure 25 Selection of network element to edit



The cost estimation tool screen will switch from the *Project Main Screen* to *Building Block Selection* screen.

2. Select building blocks

- The selected network element number, name and description will appear on the top left of the screen. The user should verify that the appropriate network element has been selected prior to assigning inputs.

- b) The five orange cells are user input fields and a dropdown list will appear upon clicking within the cells. The user must select the inputs from top to bottom (i.e. starting with *Category* and ending with *Quantity*). Upon selecting an input for each input field, a description and set of notes will appear for the corresponding selection. The description and notes serve the purpose of aiding the user with the selection process. Furthermore, the cost summary preview table on the bottom-left will be populated based on the selected building block and quantity.

Figure 26 Building block selection interface

The interface is divided into three main sections, each labeled on the right:

- Input fields:** Contains five orange input fields:
 - Category: Overhead line
 - Sub Category: HVAC
 - Voltage kV: 500
 - Details: 4 x Orange DCST 6080MVA
 - Quantity: 100 km
- Description and notes:**
 - Description:** Overhead lines double circuit single tower, quad conductor per phase
 - Notes:**
 1. Plant amount includes: Strain + Structural tower associated costs (steel tower with single earth peak, structural foundation steel, foundation leg steel, climbing barrier, fittings, insulators) and insulator and conductor. 85% suspension, 15% strain and 400m span. Sag and OPGW has been appropriately assigned
 2. Civil and structural works includes: Tower concrete footing, soil tests, installation of tower and foundations
 3. Electrical works includes: installation of conductor (setup, draw wires, stringing, clamping off), installation of OHEW/OPGW (draw wire, stringing, clamping off)
 4. Secondary system and testing and commissioning is accounted in the terminating end in the substation switchbay cost
- Cost summary preview:** A table showing costs in millions of dollars (\$M):

Costs (\$M)	
Plant	\$67,365,100
Civil and structural Works	\$52,120,750
Electrical Works	\$66,861,000
Secondary Systems	\$0
Design & Survey	\$10,099,057
Testing & Commissioning	\$0
Contractor Project Management & Overheads	\$13,982,457
Easement/ Property Costs	\$4,000,000
Environmental Offset Costs	\$24,000,000
Total	\$ 238,428,364

- c) After filling out the input fields and verifying that the appropriate selection has been made, click on the **+** button. The selected building block will be added to the user selection table on the right of the screen. Repeat *step a)* to *step b)* to add all relevant building blocks to the selected network element.
- d) To delete a selected building block, click on the **-** button. A popup will appear as shown in Figure 27 below.

Figure 27 Removing a selected building block

Building Block Number	Category	Subcategory	Title
1	Overhead line	HVAC	4 x Orange DCST 6080MVA

Select the building block from the dropdown list to be deleted and click *Delete Building Block*. A confirmation popup will appear, click *OK* to proceed delete the selected building block.

- e) To change the quantity of a selected building block, click on the button. A popup will appear as shown in Figure 28 below.

Figure 28 Changing the quantity of a selected building block

Building Block Number	Category	Subcategory	Title
1	Overhead line	HVAC	4 x Orange DCST 6080MVA

Enter New Quantity: 50

Select the building block and enter the new quantity to be applied for the building block. Click *Apply Change* and click *OK* on the confirmation popup. The quantity and total cost for the edited building block will be updated in the list of selected building blocks on the right. *Note: editing a quantity to '0' is allowed, but this quantity cannot be changed at any time in the future. It is best to delete any element that has zero quantity.*

- f) Once the user has entered all building blocks to the selected network element click on the *Edit Project Attributes* button on the top-right of the screen.

Figure 29 Progressing to next screen/step

The cost estimation tool screen will switch from the *Building Block Selection* screen to the *Network Attribute Selection* screen.

3. Select project attributes

Adding project attributes to the selected network element follows a similar process to adding building blocks. Refer to the steps in *Select Building Blocks*. The key differences are that there is:

- Less input fields
- No edit quantity button

- A progress update is available above the table of included attributes which assists the user to know how many attributes have been assigned and how many have not yet been assigned.

It is important to refer to the most relevant sources of project information describing the characteristics of the network elements and the environment it is being built on objectively and accurately.

The user should also consider the overall project size (length of line, number of bays) when making judgement on the 'project network element size' attribute (i.e. economy of scale factor) for each individual network element. For example, consider the entirety of the overhead line project size, instead of focusing only on a specific segment (i.e. network element) of the project if the project is being delivered in entirety by contracted parties.

Once the user has entered all project attributes to the selected network element click on the *Edit Risks* button on the top-right of the screen.

4. Select known / unknown risks

Adding risks to the selected network element follows a similar process to adding attributes. Refer to the steps in *Select Project Attributes*. The key differences are that there are:

- Two categories for each of transmission lines, stations, and underground cables
- Two progress counters above the inclusion table.

It is important to objectively choose the most appropriate level of risk exposure, considering all the available information at the time of building the cost estimate.

Once the user has entered all relevant risk factors to the selected network element click on the *Finish Editing Network Element* button on the top-right of the screen.

Note: If the user proceeds without adding at least one known and one unknown risk, the Cost estimation tool will automatically add a blank entry. This will not affect the calculation of the project cost estimate; however, it is needed for the Cost estimation tool to function correctly and cannot be deleted by the user. It should also be noted that although the user can proceed without selecting all unknown risks, the user must select the appropriate risks later to develop a Class 4/5 estimate.

5. Repeat Steps 1 – 4

To edit another network element, repeat steps 1 – 4.

Note: The user can re-edit a network element by clicking on the network element on the main screen and clicking the Edit Network Element button.

6. Guidance on selection of attributes/risks

The cost estimation tool provides detailed descriptions and notes to assist the user to select the appropriate attribute and risk factors for each network element.

Each project attributes have multiple choices that describes, either qualitatively or quantitatively, the various aspects of the given scope of work such as the size of the work, site geography, interface issues, delivery timing, contractual arrangements etc. that have impact on costs.

Each known risk has three levels of choice, one defined as 'Business as Usual' and two others for varying levels of risk. The use of BAU is considered the default selection where the user has no additional information about this aspect of risk.

For unknown risks, the default selection is Class 5, as the TCD has been developed primarily for production of Class 5 estimates. Class 4 may be used where significant engineering design work has

been carried out to develop the work scope and building block detail. Class 3/2/1 is intended for AEMO use only, for cross-checking of TNSP estimates of projects at advanced stages.

The TCD user should read and understand the factor and choices available to them and choose the most appropriate one that closely matches their project. Given the prerequisites as stated in the beginning of this Appendix, and the detailed descriptions and notes provided for every attribute and risk factors and their choices, the TCD user is expected to select the appropriate choices accurately reflecting the characteristics of their project. The phrasing and style of the provided descriptions and notes are intuitive and includes commonly used industry wordings to allow this.

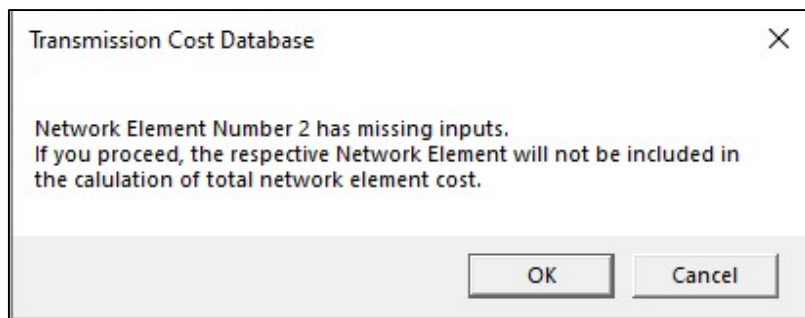
C.4.5 Step 5: Edit indirect cost

1. Edit indirect costs

Once the user has finished editing all network elements, click on *Edit Indirect Costs*. The cost estimation tool will load the *Indirect Cost Selection* screen. The time taken to load will vary depending on the number of network elements and associated inputs for the project.

Note: If the user clicks Edit Indirect Costs and has not assigned at least one entry for building blocks, project attributes and risks, a warning message will appear as shown in Figure 30 below.

Figure 30 Indirect cost warning message



The user has the option to proceed and exclude the network element from being included in the cost estimate, or to cancel and finish assigning inputs.

2. Select indirect cost fields

On the *Indirect Cost Selection* screen, select the appropriate inputs from the dropdown list in a similar manner to *Add Building Blocks*. After inputting all fields, click on the  button to refresh the indirect costs. The summary of the indirect cost categories will be updated on the right of the screen.

IMPORTANT – If the user makes ANY changes to the network element inputs (building block/project attributes/risk) in a later revision, the user MUST click the refresh button again to update the indirect costs. The exported project cost summary WILL NOT reflect the correct indirect costs if the user does not update the values prior to exporting.

Once the user has updated the indirect costs, click *Finish Editing Indirect* to go back to the *Project Main Screen*.

C.4.6 Step 6: Generate project cost summary report

When the user has finished adding network elements, editing every network element (with attribute and risk factors), and updated the indirect costs, click *Create Report* on the *Project Main Screen* as shown in Figure 31 below. The button will create a project cost estimate in a separate Excel workbook based on the user's inputs.

Figure 31 Create report button on main screen

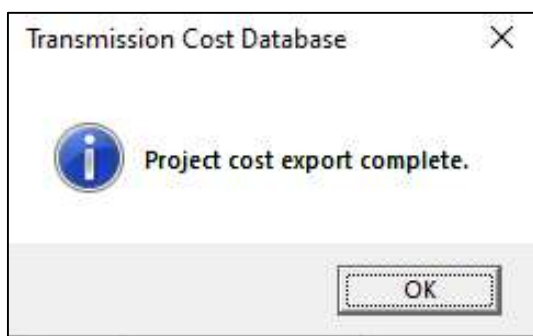


The time taken to load will vary depending on the number of network elements and associated inputs for the project.

Note: A similar warning message associated with the Edit Indirect Costs button will appear if the user has not assigned at least one entry for building blocks, project attributes and risks. If the user chooses to proceed, the exported project cost summary will omit any network element that has missing entries.

When the cost estimation tool has finished processing the data, a user alert message will appear as shown in Figure 32.

Figure 32 Alert message indicating completion of exporting outputs



Click **OK** to view the exported Excel workbook containing the project cost summary. The exported file will consist of three different project cost summary formats: *Output A*, *Output B* and *Output C*. It is recommended that the user reviews the user entries for each network element by referring to *Output C* which is a detailed cost breakdown of each network element, prior to the addition of indirect costs. *Output A* is a summary view showing the total cost for each network element, inclusive of adjustments and risks, with the addition of indirect costs. *Output B* is a summary view showing the total baseline cost for the project, adjusted baseline cost (which modifies the baseline cost based on attribute factors), known risk allowance, unknown risk allowance and indirect costs.

It is also recommended that the user saves both the cost estimation tool workbook and the exported project cost summary workbook for future reference. Furthermore, the saved cost estimation tool workbook can be edited by the user to add/remove entries in future revisions to create new project cost estimate reports.

C.4.7 Checklist

Prior to using the cost estimation tool		
1	Define project scope	Example: Deliver a new transmission line from A to B
2	Define key inputs and design	Where is it located? Easements? This will include a preliminary single line diagram

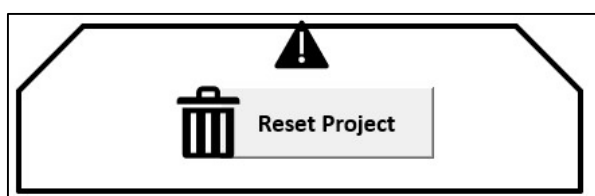
Prior to using the cost estimation tool		
3	Identify key network elements	Station, overhead lines and/or underground cables
Using the cost estimation tool		
4	Have you added the project network elements?	Check that you have added each key network element on the project main screen
5	Does your cost estimate include overhead lines?	- Check that you have added all associated overhead line building blocks - Check that you have only applied overhead line attributes/risks to overhead line elements
6	Does your estimate include station components?	- Check that you have added all associated station building blocks - Check that you have only applied station attributes/risks to station elements
7	Does your estimate include underground cable components?	- Check that you have added all associated underground cable building blocks - Check that you have only applied underground cable attributes/risks to underground elements
8	Have you applied all attributes and risks?	Check that you have applied at least one project attribute and one risk for each network element
9	Have you updated the indirect costs prior to exporting?	Check that you have selected the appropriate indirect cost categories and that you have refreshed the costs prior to exporting the data

Note: a copy of typical output views is provided in the GHD report.

C.4.8 Reset project

At any point the user can clear all inputs to the cost estimation tool by clicking the *Reset Project* button as shown in Figure 33 below.

Figure 33 Reset project button on main screen



Numerous warning messages will appear requiring user confirmation to proceed with resetting the project workbook.

IMPORTANT – Once the project has been reset, the user CANNOT recover the data.

C.5 Qualification of generated cost estimate

Please see section 10 in the body of the report.

Appendix E Blank data request templates

E.1 Station works

SUBSTATION COST DATA REQUEST TEMPLATE

(suitable for both early stage estimate for benchmarking purpose and also advanced stage estimate for database development purpose)
(applicable to network elements within the overall Project)

Cost items	\$ estimate and factor choices	Scope, quantity and cost description comments
Plant and Equipment		
Material (Large Specialist Equipment - Power Tx, HVDC Converter, Syncon, PST, SVC etc.)	\$\$\$	
Material (other primary plants)	\$\$\$	
Material (secondary plants)	\$\$\$	
Electrical works		
Electrical installation works (Large Specialist Equipment - Power Tx, HVDC Converter, Syncon, PST, SVC etc.)	\$\$\$	
Electrical installation works (other primary plants)	\$\$\$	
Electrical installation works (secondary plants)	\$\$\$	
Civil works		
Switchyard civil and structural installation works for Large Specialist	\$\$\$	
Switchyard civil and structural installation works for other primary plants	\$\$\$	
Masonry control building civil and structural installation works	\$\$\$	
Building material (demountable, comms hut)	\$\$\$	
Building installation work (demountable, comms hut)	\$\$\$	
Contractor overheads		
Contractor Project Management, Site Management, Mobilisation and demobilisation, and Contractor Overheads	\$\$\$	
Owner overheads		
Design and engineering costs	\$\$\$	
Commissioning	\$\$\$	
Related TNSP Owner Costs		
Property acquisition	\$\$\$	
Environmental costs/Biodiversity charges	\$\$\$	
Community and stakeholder engagement costs	\$\$\$	
Switching and outage management cost	\$\$\$	
Owner corporate overheads (Project Management, Site Management, HSE assurance)	\$\$\$	
Adjustment factor for project attributes (applied in		
Adjustment factor 1 (location - extreme far, regional, urban)	Select from (brackets)	Qualifying comments
Adjustment factor 2 (terrain - difficult, normal, easy)	Select from (brackets)	Qualifying comments
Adjustment factor 3 (procurement type - D&C, turnkey etc.)	Select from (brackets)	Qualifying comments
Adjustment factor 4 (delivery timeframe - tight, adequate, long)	Select from (brackets)	Qualifying comments
Adjustment factor 5 (market factor - tight, normal, excess capacity)	Select from (brackets)	Qualifying comments
Adjustment factor 6 (greenfield/brownfield)	Select from (brackets)	Qualifying comments
Adjustment factor 7 (special protection scheme - minor, typical,	Select from (brackets)	Qualifying comments
Adjustment factor 8 (.....)	Select a description for the	Qualifying comments
Known Risks (applied in project forecast)		
Risk event 1 (weather delays)	\$\$\$	The basis of risk calculation
Risk event 2 (network access and outage restriction)	\$\$\$	The basis of risk calculation
Risk event 3 (geotech findings)	\$\$\$	The basis of risk calculation
Risk event 4 (compulsory acquisition)	\$\$\$	The basis of risk calculation
Risk event 5 (environmental offset)	\$\$\$	The basis of risk calculation
Risk event 6 (....)	\$\$\$	The basis of risk calculation
Unknown Risks (these risks will start to merge into known risks as the projects advances towards CPA stage with cost being added to direct and indirect costs above). (This may be a contingency applied in project forecast)		
Unknown scope & technology risks (BAU, moderate, high)	Select from (brackets)	The basis of risk calculation/contingency added in
Unknown productivity/labour cost risks (BAU, moderate, high)	Select from (brackets)	The basis of risk calculation/contingency added in
Unknown plant procurement costs (BAU, moderate, high)	Select from (brackets)	The basis of risk calculation/contingency added in
Unknown project overhead risks (BAU, moderate, high)	Select from (brackets)	The basis of risk calculation/contingency added in

E.2 Overhead line and underground cable works

TRANSMISSION LINE and UNDERGROUND CABLE COST DATA REQUEST TEMPLATE

(suitable for both early stage estimate for benchmarking purpose and also advanced stage estimate for database development purpose)
(applicable to network elements within the overall Project) *Please include total cost in column C, and specify length (km) in column D

Cost items	\$ estimate and factor choices	Scope, quantity and cost description comments
Materials		
Material (overhead conductor)	\$\$\$	
Material (OPGW/EW)	\$\$\$	
Material hardware (insulators, fittings)	\$\$\$	
Material structure (towers, poles)	\$\$\$	
Material (underground cable)	\$\$\$	
Material (underground temperature monitor, telecommunication etc)	\$\$\$	
Material hardware (joints, terminations)	\$\$\$	
Electrical works		
Overhead electrical installation works (insulator install, stringing)	\$\$\$	
Underground electrical installation works (jointing, termination)	\$\$\$	
Civil works		
Overhead civil and structural installation works	\$\$\$	
Easement Access and Clearing	\$\$\$	
Underground civil works (trenching, drilling, surface reinstatement, joint pits)	\$\$\$	
Underground civil works (winching, cable laying)	\$\$\$	
Contractor overheads		
Contractor Project Management, Site Management, Traffic management, Safety barriers, Mobilisation and demobilisation, and Contractor Overheads	\$\$\$	
Owner overheads		
Survey, design and engineering costs	\$\$\$	
Commissioning	\$\$\$	
Related TNSP Owner Costs		
Easement acquisition	\$\$\$	
Environmental costs/Biodiversity charges	\$\$\$	
Community and stakeholder engagement costs	\$\$\$	
Switching and outage management cost	\$\$\$	
Owner corporate overheads (Project Management, Site Management, HSE assurance)	\$\$\$	
Adjustment factor for project attributes (applied in estimates)		
Adjustment factor 1 (location - extreme far, regional, urban)	Select from (brackets)	Qualifying comments
Adjustment factor 2 (terrain - difficult, normal, easy)	Select from (brackets)	Qualifying comments
Adjustment factor 3 (procurement type - D&C, turnkey etc.)	Select from (brackets)	Qualifying comments
Adjustment factor 4 (delivery timeframe - tight, adequate, long)	Select from (brackets)	Qualifying comments
Adjustment factor 5 (market factor - tight, normal, excess capacity)	Select from (brackets)	Qualifying comments
Adjustment factor 6 (greenfield/brownfield)	Select from (brackets)	Qualifying comments
Adjustment factor 7 (special protection scheme - minor, typical,	Select from (brackets)	Qualifying comments
Adjustment factor 8 (.....)	Select a description for	Qualifying comments
Known Risks (applied in project forecast)		
Risk event 1 (weather delays)	\$\$\$	The basis of risk calculation
Risk event 2 (network access and outage restriction)	\$\$\$	
Risk event 3 (geotech findings)	\$\$\$	
Risk event 4 (compulsory acquisition)	\$\$\$	
Risk event 5 (environmental offset)	\$\$\$	
Risk event 6 (.....)	\$\$\$	
Unknown risks (these risks will start to merge into known risks as the projects advances towards CPA stage with cost being added to direct and indirect costs above). (This may be a contingency applied in projects forecast)		
Unknown scope & technology risks (BAU, moderate, high)	Select from (brackets)	The basis of risk calculation/contingency
Unknown productivity/labour cost risks (BAU, moderate, high)	Select from (brackets)	The basis of risk calculation/contingency
Unknown plant procurement costs (BAU, moderate, high)	Select from (brackets)	The basis of risk calculation/contingency
Unknown project overhead risks (BAU, moderate, high)	Select from (brackets)	The basis of risk calculation/contingency

Appendix G Functional Specification

Appendix G Functional Specification

Level 15 133 Castlereagh Street Sydney NSW 2000 Australia

61 2 9239 7100
sydmail@ghd.com

© GHD 2021. This document is and shall remain the property of GHD Advisory. The document may only be used for the purpose for which it was commissioned and in accordance with the Terms of Engagement for the commission. Unauthorised use of this document in any form whatsoever is prohibited.

Rev.No.	Authors	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Draft	Anuraag Malla, Tyla Ono	Ian Nichols	[email]	Bruce Clarke		26/02/2021
Final	Anuraag Malla, Tyla Ono	Ian Nichols	[email]	Bruce Clarke		19/03/2021
Addendum	Anuraag Malla, Ian Nichols	Patrick Ross-Taylor	[email]	Bruce Clarke		07/05/2021