Energy Queensland Revised Regulatory Proposal

Risk Quantification Methodology

Energy Queensland

Reference: 506696

Revision: 1

2019-12-04

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1 Introduction

Aurecon has been contracted by Energy Queensland to develop a series of risk quantification models. The primary purpose of this development work is to enable Energy Queensland to incorporate quantified risk-based analysis into its asset management processes. Energy Queensland is committed to the use of new tools and methods to support investment optimisation and best-practice asset management as per ISO55000. This risk-based approach is a key step in enhancing asset management capability and supporting economic outcomes for customers.

The main trigger for this work is the requirement of the Australian Energy Regulator (AER) for distributors such as Energex and Ergon Energy to incorporate risk quantification in their justification business cases for replacement capital planning. A number of risk quantification business cases have been developed for this purpose.

2 Overview of Program

2.1 Objectives

The key objectives of the program to develop risk models are:

1. Use widely understood, **industry accepted** techniques which are **simple** and transparent
2. Models should be consistent with the AER Industry Guideline for Replacement Capital Planning
3. Develop a robust methodology, thus improving the value and defendability of analysis and demonstrating a prudent approach to asset management.
4. A practical solution which can be verified and developed, working with existing data constraints and adaptable to future data sources.

2.2 Approach

Aurecon adopted the following collaborative approach with Energy Queensland in the development of the risk quantification models:

Step 1: Identify a risk quantification methodology - may include CBRM, Weibull, or other probabilistic methods;

Step 2: Develop risk quantification parameters including key parameters such as cost of consequence figures, disproportionality factors, probability of severity

Step 3: Obtain feedback from Energy Queensland - workshop to agree to proposed approach

Step 4: Develop risk models for each proposed asset class / program

Step 5: Produce results for each proposed asset class / program

Step 6: Test the results with Energy Queensland and document the results into business cases

This consultative approach enabled Energy Queensland key subject matter experts to play a strong role in the development of the methodology, the models and take responsibility for the key inputs and model results.

2.3 Targeted Programs and Projects

The key programs targeted for this initial risk quantification phase were selected based on feedback from the AER on the critical replacement capital programs that needed further justification in the 2020-25 AER determination process. These programs are shown in table 1 below.

Table 1: Energy Queensland Targeted Programs for Risk Quantification

Program / Project Name	Program / Project Description
Ergon Energy Clearance to Structure / Clearance to Ground (CTS/CTG)	Remediation program to address known clearance defects
Ergon Energy LV Services	Replacement program to address defective assets
Energex LV Services	Replacement program to address defective assets
Energy Queensland LV Safety program	Program of LV monitoring to detect neutral integrity failures
Ergon Energy Poles	Replacement program to address defective assets
Ergon Energy Pole Top Structures	Replacement program to address defective assets
Ergon Energy Childers to Gayndah feeder	Condition based replacement program of 66kV overhead line
Ergon Energy Circuit Breakers	Replacement program to address end of life equipment
Ergon Energy Power Transformers	Replacement program to address end of life equipment

2.4 Scope of This Document

This document sets out the methodology, approach and key sources of information used for risk quantification. Details of the analysis including the parameters in each case, are contained in the risk models and business cases for the specific programs.

3 Risk Quantification Methodology

3.1 Methodology Overview

The AER's Industry Application Note for Asset Replacement Planning[1] provides guidance on a suitable methodology for risk quantification. This application note provides the general formula for risk quantification as follows:

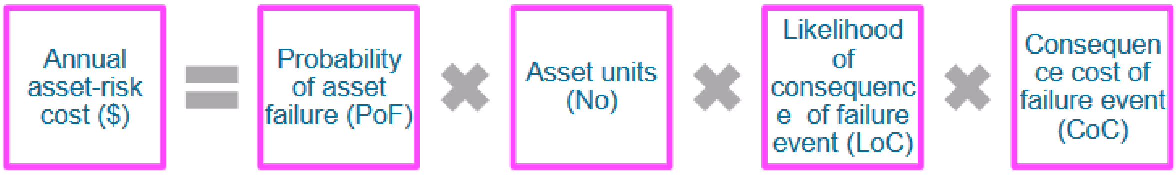

Figure 1: General Formula for Risk Quantification

Aurecon has adopted this approach in general and has used a range of different modelling techniques to determine the individual elements. These key elements are shown in the table below.

Table 2: Approach Used for Risk Quantification Modelling

Program / Project Name	Probability of Failure Approach	Likelihood of Consequence Approach	Cost of Consequence Approach
Ergon Energy Clearance to Structure / Clearance to Ground (CTS/CTG)	Model known failure quantities	Use EQ Network Risk Framework to Identify risk consequence categories. Key risk categories used: - Safety - Customer reliability - Environment - Business costs (includes fire and emergency remediation)	Industry Standard Approach – detailed below
Ergon Energy LV Services Population	Weibull model of forward failure rates		
Energex LV Services Population	Weibull model of forward failure rates		
Energy Queensland LV Safety program Population	Weibull model of forward service failure rates		
Ergon Energy Poles Population	Weibull model of forward failure rates		
Ergon Energy Pole Top Structures Population	Weibull model of forward failure rates		
Ergon Energy Childers to Gayndah feeder	Past Failure rates projected forward using linear extrapolation		
Ergon Energy Circuit Breakers	Weibull model of forward failure rates		
Ergon Energy Power Transformers	Weibull model of forward failure rates		

[1] Australian Energy Regulator, Industry Application Note, Asset Replacement Planning, January 2019

3.2 Probability of Failure Approach

The various approaches to Probability of Failure (PoF) are detailed below:

3.2.1 Known Failures

For the known failure category of CTS/CTG – the probability for known events is 1.0 and the modelling uses the total quantity of these events to determine risk outcomes. No further forecast failures have been modelled over and above the current quantity of known defects.

3.2.2 Single Asset - Known Failures

For the Chiders to Gayndah line the past failures of the asset are well documented. The failure rate has been determined based on this historical information and a forward projection has been made based on a simple linear extrapolation of the historical failures.

3.2.3 Individual Asset Programs

For Circuit Breakers and Power Transformers each individual asset has been separately modelled. The failure rate has been projected into the future using a Weibull function with parameters based on industry standard information.

3.2.4 Population Programs

For the population programs (LV services, Poles, Pole Top Structures) a Weibull function was used to model the future failures rates. The process for derivation of the parameters was as follows:

Step 1: Obtain population age profile from Energy Queensland data sources

Step 2: Determine initial Weibull function parameters based on industry standard information

Step 3: Calibrate initial year failure rate based on current known failures, using actual failure data from Energy Queensland where possible

Step 4: Extrapolate 5-10-year failure quantities based on historical failure rate data from Energy Queensland (EQ)

Step 5: Fine tune Weibull parameters to align to starting and future failure quantities to the extent possible

3.3 Likelihood of Consequence

The Likelihood of Consequence (LoC) is the probability that an asset failure will result in a particular defined risk consequence. The approach to developing this information was based on industry practice:

LoC = incident conversion rate (ICR) × probability of severity (PoS)

3.3.1 Incident Conversion Rate

The ICR is the ratio of safety incidents / total incidents. As an example, in the case of Ergon LV services, some 1700 service failures / year occurred in recent years (source EQ Asset Management Plan Services). Of these failures, some 180 service-related shocks / year occurred (source EQ Asset Management Plan Services). This provides an incident conversion rate of 180/1700 = 10.6%. This effectively means that 10.6% of service failures could result in some form of safety-related incident. A similar process was used for other assets and other consequence categories, and in some cases where direct data was unavailable, estimates were made for the incident conversion rates. Where possible these estimates were cross-checked with other data for validation purposes.

3.3.2 Probability of Severity

The Probability of Severity (PoS) data was derived as follows:

Step 1: Identify the risk consequences for an asset failure. This was typically done using the standard risk consequence categories from Energy Queensland Network Risk Framework (see also example consequence scale in Appendix A), and with reference to the threat barrier diagrams in EQ's Asset Management Plans, plus the semi-quantitative risk assessments contained in various existing justification documents. The threat barrier diagrams identify the typical failure modes, the existing controls and the possible risk consequence scenarios resulting from asset failures. The typical risk consequence categories used were:

- **Safety** – examples of safety consequences include single fatality or serious injury
- **Customer** – an example of this is a loss of supply event
- **Business** – examples of this include initiating a fire, or costs for emergency response / remediation of an asset failure
- **Environment** – an example is the environmental harm due to an oil spill

Step 2: Use the EQ Network Risk Framework to identify the consequence severity category scale suitable for this type of risk. For example, a safety related incident could result in a category 4 (Multiple serious injuries) or 5 (single fatality) consequence.

Step 3: Assign PoS estimates to each of the risk consequence categories utilised for a particular asset failure. These estimates were based on industry data or based on known information where available. A PoS for a fatality (Safety consequence category 5) could have a value of 1.0% for example, meaning that for the asset failures that become safety incidents, 1.0% of these could result in a fatal injury.

Step 4: Cross-check overall LoC against known data for each consequence category. In the case of the fatality example, the overall likelihood of consequence produced by the model (e.g. 1 fatality in 10 years) can be cross-checked against historical information for similar incidents.

Step 5: Adjust PoS as required to calibrate the LoC outcomes against the known data points, or where data is not available, test the result with experienced staff to ensure that outcome is reasonable, given the circumstances and known history.

3.4 Cost of Consequence

The Cost of Consequence (CoC) is the final step in the determination of the quantified risk.

3.4.1 Safety Consequences

Aurecon has developed a proposed safety risk consequence monetisation framework for Energy Queensland, based on analysis of other industry sectors, other Australian NSPs (Ausgrid & Ausnet) and EQ's existing Network Risk Framework consequence risk scales. The figures have been derived from Value of Statistical Life (VSL) estimates publicly available from the Federal Government[2].

The Disproportionality Factor (DF) is based on the gross disproportion, which is the perceived point at which the cost of implementing a safety measure grossly exceeds its expected benefits. The DF is the factor applied to the benefit to offset the gross disproportion, depending on the severity of the safety consequence.

Disproportionality factors used in this analysis have been derived from a review of typical industry practices and are shown in the table below.

[2] https://www.pmc.gov.au/sites/default/files/publications/value-of-statistical-life-guidance-note_0_0.pdf

Table 3 : Safety Consequence Values and Disproportionality Factors

Consequence	Monetisation	Disproportionality Factor	Source
6 (Multiple Fatalities)	$9,800,000	Not Used	N/A
5 (Single Fatality)	$4,900,000	10	Industry peers
4 (Multiple Serious Injuries)	$490,000	8	Industry peers
3 (Single Serious Injury)	$49,000	6	Industry peers
2 (Minor Injury)	$4,900	4	Industry peers
1 (Very Low Injury)	$490	2	Industry peers

3.4.2 Customer Consequences

Aurecon has adopted the Value of Customer Reliability figures produced by the Australian Energy Market Operator (AEMO)[3]. These figures have been used in all modelling for the determination of customer outage costs.

3.4.3 Business Consequences

Business risk consequences can include fire, and costs for emergency response / remediation of asset failures. Specific assumptions have been made in each model depending on the nature of the asset and the likely consequences. For example, in the case of LV services, the fire consequence (Consequence level 2) has an estimated value of $264,000 which relates to the cost of a house fire. In other risk models, where the risk scenario is different, then another value may be utilised. For example, for the Childers-Gayndah case the bushfire risk consequence (level 5) has been estimated to be significantly higher at $5.0M based on the circumstances and location of that asset. The costs for remediation of asset failures in the large population cases (services, poles, pole top structures) have been estimated for the population models using a multiplier of 2.5 times the standard unit cost. This cost has been estimated based on EQ's experience with emergency replacement, including cost of attending, replacement works, reporting and follow up.

3.4.4 Environment Consequences

The cost for environmental consequences has only been used where specific consequence scenarios have been identified. For example, the environmental risk consequence category has not been used for the population models or for Childers-Gayndah due to limited impact of asset failures in these categories on the environment. It has been used however for power transformer modelling, in sites where inadequate or non-existent bunding could result in a significant oil spill and resulting clean-up. The unit cost for such an event has been modelled on actual cases where these events have occurred.

3.5 Overall Risk Cost Cross-Checks

The Aurecon model calculates the risk cost for each of the consequence categories and sums these to a total annual risk cost as per the formula detailed in 3.1. Each of these annual risk costs were then sense-checked to ensure that there were no anomalies. For example, the annual fatality cost is compared to the unit fatality cost to ensure that the modelled frequency of these events (e.g. 1 fatality in 10 years) is consistent with known history.

[3] https://www.aemo.com.au/-/media/Files/PDF/AEMO_FactSheet_ValueOfCustomerReliability_2015.pdf

4 Program Justification Methodology

For each of the programs or projects, Aurecon has conducted an economic analysis using EQ's NPV model to determine the NPV of the program. Several key assumptions have been used in this analysis as detailed below.

4.1 Counterfactual Case Definition

For each program, a counterfactual case has been defined. In general, this has been defined as the historical spend case.

In most cases the modelled comparative options analysis includes the historical replacement programs (typically inspection and remediation based), as well as higher quantity proactive programs in cases where escalating asset failure rates necessitate a reduction / stabilisation of asset failures. This analysis provides the baseline of asset failures, the current control regime (typically inspection and remediate) and the proposed program. From this analysis a view of the risk benefits of various programs can be compared to ensure that the programs are sustainable in the longer term as well as economically justified in the short to medium term.

A full list of the counterfactual definitions and rationale is provided in the table below.

Table 4: Counterfactual Definition and Rationale

Program / Project Name	Counterfactual Definition	Rationale
Ergon Energy (CTS/CTG)	Assume that no defects are remediated over study period	Need to understand the risk costs for do nothing to enable a valid assessment of various remediation options against the known risks.
Ergon Energy LV Services Population	Historical replacement rates	Compare proposed option to historical approach
Energex LV Services Population	Historical replacement rates	Compare proposed option to historical approach
Energy Queensland LV Safety program Population	Historical replacement rates	Compares costs and benefits of additional monitor programs with base case services programs, using services program risks
Ergon Energy Poles Population	Historical replacement rates	Compare proposed option to historical approach
Ergon Energy Pole Top Structures Population	Historical replacement rates	Compare proposed option to historical approach
Ergon Energy Childers to Gayndah feeder	No replacement of feeder assumed	Repair costs as well as risk costs for failures included in forward risk program
Ergon Energy Circuit Breakers	No replacement assumed for each specific asset	Need to understand failure risk costs for each asset to enable replacement cost to be evaluated
Ergon Energy Power Transformers	No replacement assumed for each specific asset	Need to understand failure risk costs for each asset to enable replacement cost to be evaluated

4.2 Study Period Definition

For each program a study period has been chosen. These study periods and the rationale in each case are described in the table below.

Table 5: Study Period Definition and Rationale

Program / Project Name	Study Period	Rationale
Ergon Energy (CTS/CTG)	20 Years	Study period used to enable valid comparison of replacement options over 5, 7 and 10-year periods.
Ergon Energy LV Services Population	20 Years	Study period used to test longer term stability of remediation program, given increasing failures from the population.
Energex LV Services Population	20 Years	Study period used to test longer term stability of remediation program, given increasing failures from the population.
Energy Queensland LV Safety program Population	20 Years	Study period used to test longer term stability of remediation program, given increasing failures from the population.
Ergon Energy Poles Population	20 Years	Study period used to test longer term stability of remediation program, given increasing failures from the population.
Ergon Energy Pole Top Structures Population	20 Years	Study period used to test longer term stability of remediation program, given increasing failures from the population.
Ergon Energy Childers to Gayndah feeder	40 Years	Longer study period used to compare costs and benefits over the approximate life of the new feeder asset.
Ergon Energy Circuit Breakers	30 Years	Study period formulated as a compromise between full asset-life model versus short-term benefit model.
Ergon Energy Power Transformers	30 Years	Study period formulated as a compromise between full asset-life model versus short-term benefit model.

4.3 NPV Analysis

A Net Present Value (NPV) analysis was then conducted for each case using the above parameters to determine the overall value from each program / project. This analysis produced an NPV result and also tested the results for sensitivity to changes in a number of key parameters to determine the robustness of the proposed option analysis. This analysis and the details of all modelling are included in each business case.

Appendix A: Extracts of Energy Queensland Risk Framework

Figure 2 – Energy Queensland Enterprise Risk Framework

Network Risks - *Risk Tolerability Criteria and Action Requirements*

Risk Score	Risk Descriptor	Risk Tolerability Criteria and Action Requirements			
30 – 36	***Intolerable*** *(stop exposure immediately)*				
24 – 29	***Very High Risk***	***ALARP** Risk in this range managed to As Low As Reasonably Practicable	**Executive Approval** (required for continued risk exposure at this level)	May require a full Quantitative Risk Assessment (QRA) Introduce new or changed risk treatments to reduce level of risk Periodic review of the risk and effectiveness of the existing risk treatments	**SFAIRP** Risks in this area to be mitigated So Far as is Reasonably Practicable
18 – 23	***High Risk***		**Divisional Manager Approval** (required for continued risk exposure at this level)	Introduce new or changed risk treatments to reduce level of risk Periodic review of the risk and effectiveness of the existing risk treatments	
11 – 17	***Moderate Risk***		**Group Manager / Process Owner Approval** (required for continued risk exposure at this level)	Introduce new or changed risk controls or risk treatments as justified to further reduce risk Periodic review of the risk and effectiveness of the existing risk treatments	
6 – 10	**Low Risk**				
1 to 5	***Very Low Risk***		No direct approval required but evidence of ongoing monitoring and management is required	*Periodic review of the risk and effectiveness of the existing risk treatments*	

Figure 3 Energy Queensland Example Consequence Scale

SAFETY CONSEQUENCE SCALE

Consequence Scale	Degree of Personal Harm	Examples of Types of Harm	Degree of Non-Fatal Harmful Effects Incapacity Disability Impairment	Duration of Non Fatal Harmful Effects Discomfort / Pain / Disability / Impairment	Duration of Business Effects Disabling / Reduced Productivity / Alternate Work / Lost time	Treatment Required	Required Administrative / Regulatory Response
6	Multiple Fatalities / Incurable Fatal Illnesses						
5	Single Fatality / Incurable Fatal Illness		Irreversible Total				
4	Multiple Serious Injuries / Illnesses	Quadriplegia / complete loss of vision / hearing / mobility	Irreversible partial >30%	Permanent / Indefinite / Years	Permanent / Enduring approx months	Hospitalisation - Inpatient / long term / months extensive rehabilitation	
3	Single Serious Injury / Illness	Amputation / paralysis of a limb / severe burns / loss of vision / hearing / mobility	Irreversible partial <30%	Long term / Enduring / Days	Long term / >1 day < 1 week	Hospitalisation - Inpatient / short term / days some rehabilitation	External Record & Report Required
2	Minor Injury / Illness	Cuts / burns / strains / sprains	Reversible partial >30%	Short term / approx hours	Short term <1 day	Medical / Outpatient (Doctor) / limited rehabilitation	
1	Low Level Injury / Illness	Scratches / bruises	Reversible partial <30%	Temporary / approx minutes	Approx minutes	First Aid or less	Internal Record & Report Required

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