31 January 2023

Attachment 5.4.e: CBA approach for replacement program

Ausgrid's 2024-29 Regulatory Proposal

Empowering communities for a resilient, affordable and net-zero future.

Ausgrid

Table of Contents

1 Introduction

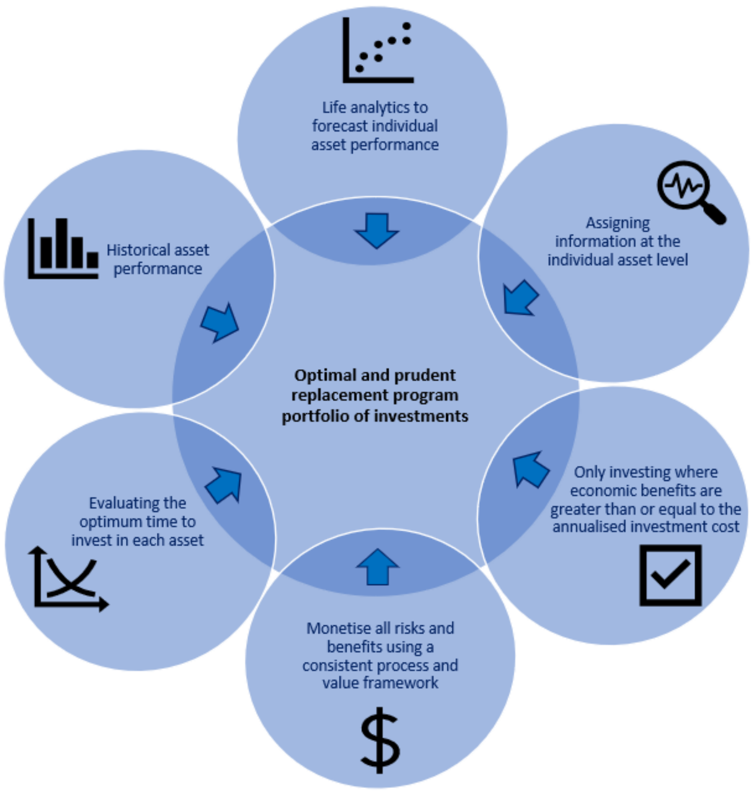
A key aspect to effective asset management is maintaining a strong and consistent basis for decision making. Through evolutions in data capture, storage and analytical processing power, decision making is becoming more data driven and evidenced based, enabling decisions at all levels to be supported by recorded and systemic experiences.

The approach undertaken for cost benefit analysis (CBA) of replacement programs is detailed in this CBA Approach for Replacement Programs Model Framework (Model Framework). This document provides an overview of the functional characteristics of the Asset Replacement CBA Model (the asset CBA model) developed to support the long term forecast for the replacement programs through risk-based decision making.

The asset CBA model applies the principles of risk management to asset related decision making to enable the selection of the optimal and prudent asset replacement investments that deliver customer value and balances risk, cost and performance in-line with Ausgrid's corporate, asset management and regulatory objectives. This is achieved by undertaking the following (and as shown in Figure 1):

- using actual historical asset performance (i.e. lived experience) where available,
- assigning detailed information against individual assets,
- forecasting the performance of individual assets using advanced statistics,
- monetising all risks and benefits using a consistent process and value framework,
- evaluating the optimum time to invest in individual assets,
- only undertaking an investment where the economic benefits are greater than or equal to the annualised investment cost, and
- aggregating the forecast performance of millions of individual assets, through billions of calculations to produce a 'portfolio view' of asset health, risk, investment, and economic value to facilitate strategic decision making.

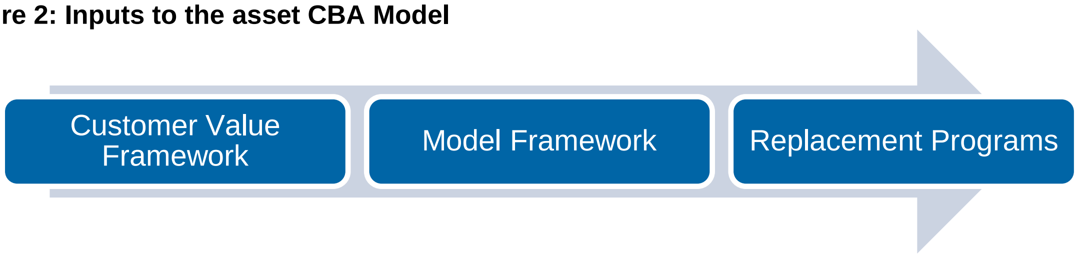
Figure 1: Inputs to the asset CBA Model



1.1 Scope

This document details the application of the quantitative decision-making modelling Ausgrid has utilised to inform asset replacement programs. Inputs from the Customer Value Framework (**Attachment 5.2.c**) are combined with asset performance data as detailed in this Model Framework.

Figure 2: Inputs to the asset CBA Model



Outputs from the model are documented as a set of replacement programs and are summarised in **Attachment 5.4.a Asset Replacement Programs**.

1.2 Risk Based Decision Making

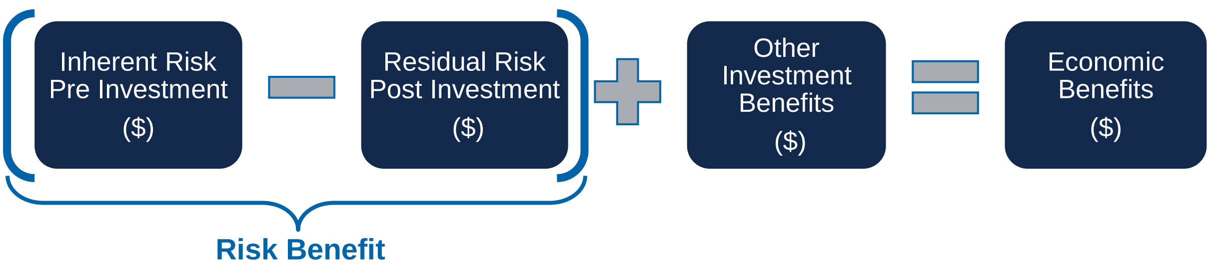
Risk management and economic evaluation techniques have been adopted and combined to support replacement decisions. The decision-making techniques utilised are based on *AS/NZS ISO 31000:2018 Risk Management Guidelines* (ISO31000) and *AS/NZS IEC 31010:2020 Risk Management — Risk Assessment Techniques* (IEC31010). The approach to asset and network risk management and decision making is captured within the Asset Management System (AMS) in-line with *AS/NZS ISO55001:2014 Asset Management System*.

Asset risks and costs avoided from investment are identified and analysed through historical performance data and subject matter expert input, then monetised and represented as an economic benefit to enable evaluation against the cost of replacement related activities. The process of identification, analysis and evaluation is consistent with good practice risk management. CBA is used to evaluate the investment using the following formula:

Figure 3: Simplified CBA

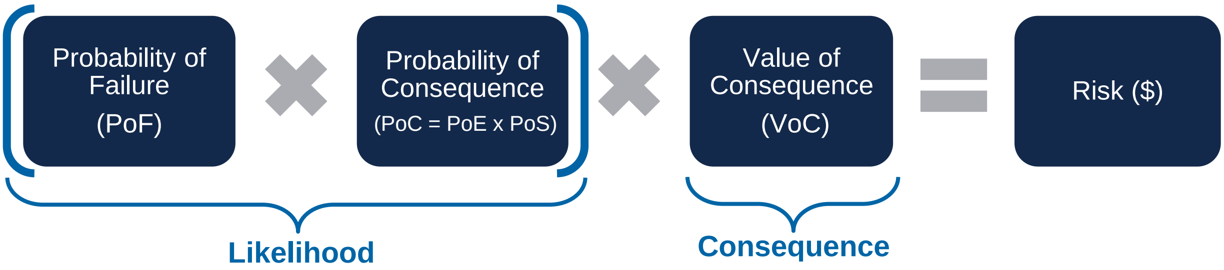
Where the CBA Ratio (also known as the benefit-cost ratio) exceeds 1, the economic benefits exceed the cost of replacement and therefore the replacement provides sufficient economic benefit to support the investment. The risk benefit (or risk avoided) is the difference between the 'inherent risk' (risk before investment) and the 'residual risk' (risk following investment).

Figure 4: Determining economic benefit



Risk is a product of the likelihood of an adverse event (i.e. incident) occurring and the consequences if that incident was to occur. The components of this calculation are highlighted in the following formula.

Figure 5: Analysing and Monetising Risk



Life analytics establishes relationships between asset failures and detailed asset information (characteristic, measurement, geospatial and other information) for the purpose of generating individual asset failure parameters to predict asset failure rates / Probability of Failure (**PoF**).

The Probability of Consequence (**PoC**) brings together asset and incident performance information and consists of the probability of realising a hazardous event (Probability of Event, **PoE**), and the probability of the scale of the consequence if the hazardous event was realised (Probability of Severity, **PoS**). The Value of Consequence (**VoC**) is the monetised economic impacts to Ausgrid and the community that are expected to arise from the occurrence of adverse events (e.g. asset failure and potential hazardous events). The VoC that the asset CBA model uses for each consequence in the analysis is defined within the Customer Value Framework.

To accurately reflect the risk carried by each asset, the sequence of events from an initial cause to the resultant realised consequence is mapped out as shown in the example in Figure 6. This assessment only includes risks where the cause relates to deterioration of the asset (‘Asset’ cause), so that only the risks that can be appropriately managed by asset replacement are included[1].

Figure 6: Example Hazardous Event: Contact with live fallen wires Cause to Effect

'Asset' Cause	Conductor Deterioration	This represents the cause of the loss of control event, such as asset deterioration
Loss of Control Event (LOCE)	Conductor Failure	Includes asset failure or breach of safety clearances
Hazardous Event (HE)	Contact with live fallen wires	This represents the event that may be realised from the loss of control
HE Consequence	Electric shock	These are the potential consequences from the realised hazardous event
Severity	Moderate Injury	The level of impact associated with the consequence

Each step in this sequence requires the realisation of the preceding step. For example, if the conductor failure is avoided, there is no risk of contact with live fallen wires. If there is no contact with

[1] Asset failures that occur during storms, bushfires and other natural disaster events have been excluded from this modelling to avoid overlap with Ausgrid’s resilience program

live fallen wires, there is no risk of electric shock. In developing the view of avoided risk, probabilities are applied to each step in the sequence.

1.3 Input Data

The approach taken to forecasting and quantitative risk assessment requires data on the performance the assets. Where available, data inputs are sourced from historical performance. Where not available, certain inputs may be informed by assumptions guided by organisational expertise or benchmarking with relevant industry peers. For example, if there were no records of a safety incident of a particular severity during the data observation period, it does not mean that one will never occur.

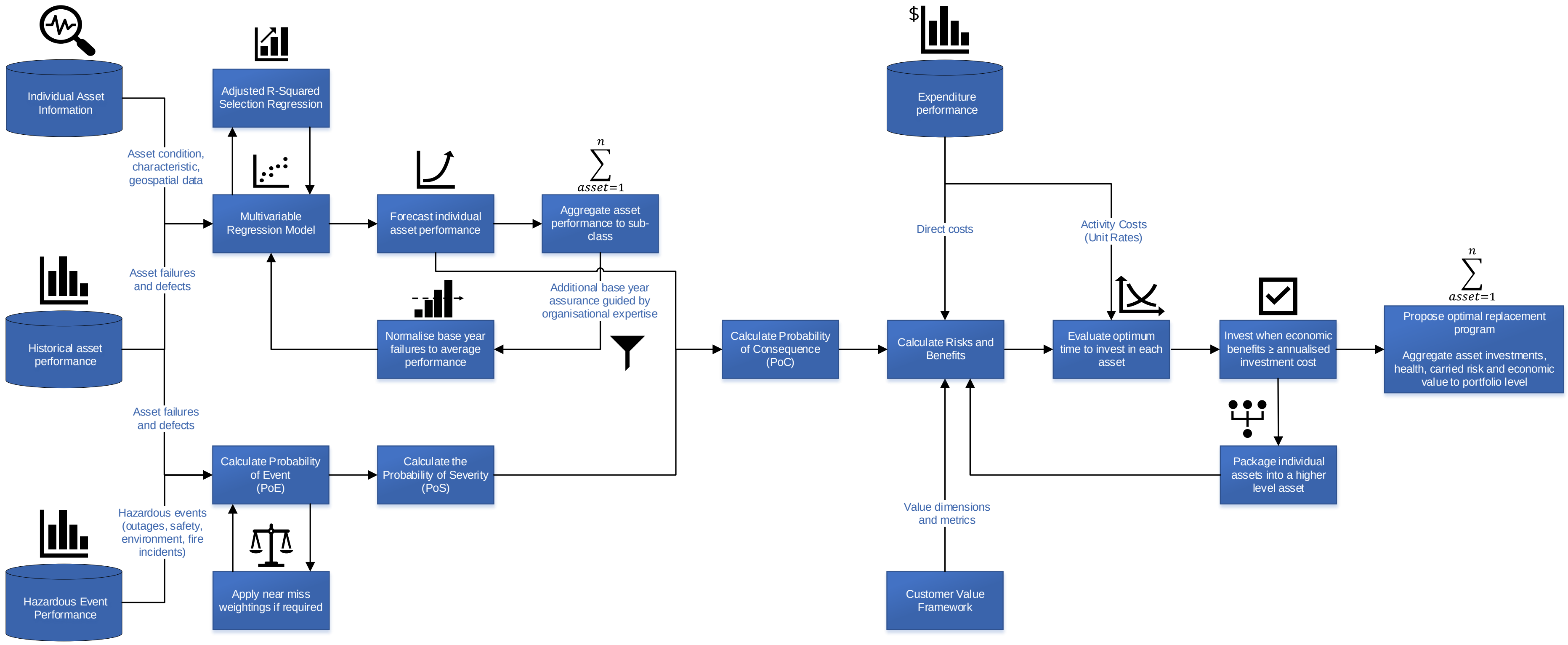
> *To support the appropriateness of the input data used and assumptions applied in the asset CBA model validations and sensitivities have been developed. These are captured within 'call-out' boxes like this throughout the document.*

The inputs and processes used to calculate the avoided risk and perform the CBA are shown in Figure 7. The number of historical data years included in the analysis is known as the 'observation period'. The observation period of the input data needed to be carefully selected as:

- if too short a period, forecasts may be skewed by outliers in performance, and
- if too long a period, forecasts may not be a true reflection of the current business environment and performance.

Given asset performance can fluctuate year to year, a 'base year' approach has been adopted for all inputs by taking the average of the previous 5-years of performance data. 5-years was considered the appropriate data observation period as it best reflects recent asset performance trends, the policies and practices most recently implemented by the business and provides sufficient data points to establish the relevant statistical relationships required to accurately forecast future performance.

Figure 7: Inputs and processes to calculate the risk and perform CBA



1.4 Regulatory Requirements

The asset CBA model is guided by the need to align with regulatory rules, guidelines and stakeholder expectations. In the regulatory context, the Model Framework supports the development of an efficient and prudent investment portfolio that maximises the benefits to customers in a planned and timely manner.

The Customer Value Framework outlines Ausgrid's alignment with the National Electricity Objectives (NEO) within the National Electricity Rules through the application of monetised risks and benefits consistent with the NEO.

The AER industry practice application note for asset replacement planning[2] (the ARP note) is the key source of regulatory guidance for asset risk (benefit) modelling. The Model Framework has been developed with the aim of consistency with the ARP note.

1.5 Model Overview

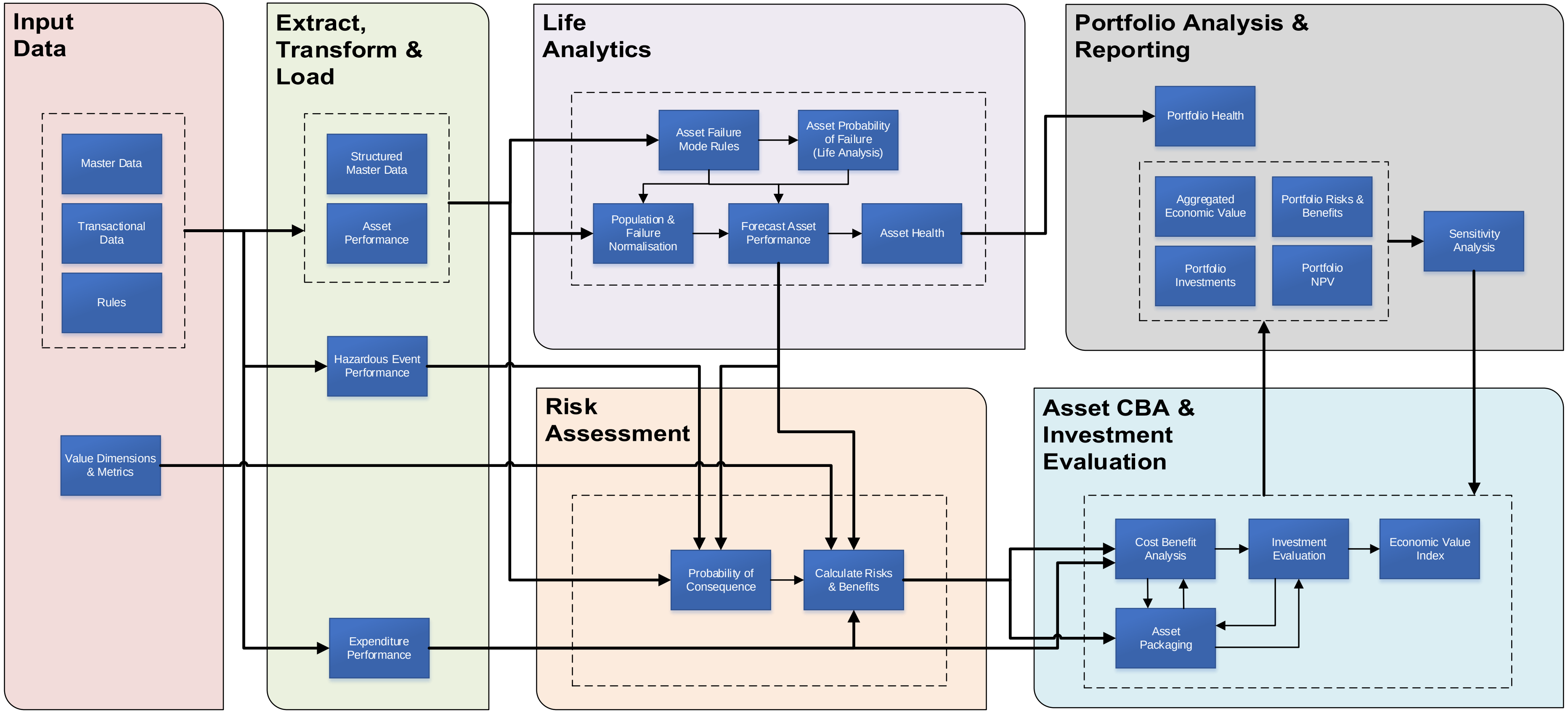
This section provides an overview of the basic principles and process modules applied in the asset CBA model to optimise asset risk-based decision making. The primary steps in the process are:

1. Determining the different data inputs to be utilised,
2. Extracting the relevant data from those inputs and transforming it for upload into the subsequent processes,
3. Undertaking failure analysis to forecast future asset failures,
4. Undertaking a risk assessment through the calculation of the probability of consequence and monetisation of risks and benefits,
5. Undertaking cost benefit analysis and economic evaluation,
6. Determining investment requirements from the asset CBA model output, and
7. Aggregating results to a portfolio level risk.

Figure 8 provides an overview of the model inputs, module interdependencies and the process flow. The following sections provide detail on the application of this model based on processes captured within Figure 8.

[2] AER ARP note

Figure 8: Overview - Asset Replacement CBA Model



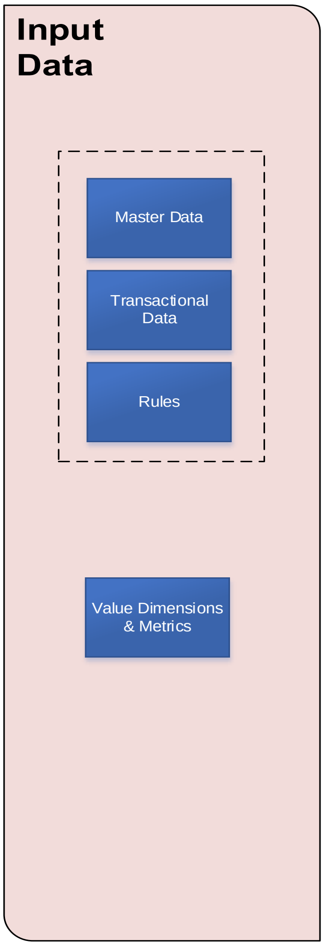
1.6 Related documents

Att #	Document name
5.1	Proposed Capex
5.2.c	Customer Value Framework
5.3.d	Principles of Cost Benefit Analysis
5.4.a	Asset Replacement Programs
5.4.f	CBA Approach for Major Projects
5.4.g	Independent review of CBA modelling (consultant report - Cutler Merz)

2 Input Data

The asset CBA model is used to support asset decisions utilising the best available input data from a range of corporate systems. Input data used in the asset CBA model is split into the following types:

- Master data,
- Transactional data,
- Rules, and
- Value dimensions and metrics.



2.1 Master Data

Master data includes the key information about assets that remains unchanged over a period of time. This information can be used to characterise and distinguish between assets. Asset master data includes but is not limited to:

- Asset population,
- Asset age,
- Asset type (i.e. asset make/model),
- Asset physical and electrical characteristics, and
- Asset geospatial characteristics.

Master data includes geospatial data from Ausgrid's Geospatial Information System (GIS) and discrete asset data from Ausgrid's Enterprise Resource Planning (ERP) system SAP. Network assets are categorised as either linear assets or discrete assets as detailed in Table 1Table 1.

Table 1: Asset Master Data Types

Asset Type	Asset Type Definition	Asset Type Description
Linear Assets	Underground cable portion-section	This is a length of cable of a single conductor type and of a certain installation type (e.g. cable laid within a duct). This length of cable is bounded by either two terminations (e.g. joints) or between a termination and installation type or between installation types.
	Overhead mains span	This is a length of overhead conductors on an individual circuit between two supporting structures (e.g. poles).
Discrete Assets	Single equipment unit	An individual asset (e.g. a pole, pillar, transformer or circuit breaker).

2.2 Transactional Data

Transactional data, unlike master data, is dynamic and can change over time. It can represent an event that relates to the master data. Transactional data associated with network assets includes but is not limited to:

- Asset failures,
- Asset defects,
- Asset measurement readings,
- Work orders, and

- Incident data.

Asset transactional data is categorised as detailed in Table 2Table 2.

Table 2: Asset Transactional Data Types

Transactional Data Type	Asset Type Definition	Asset Type Description
Asset Failures	Functional failure of an asset including the associated root cause (i.e. failure mode)	An asset failure is identified and raised against an asset master data record when an asset has ceased to perform its intended function.
Asset Defects	Conditional defect including the associated root cause (i.e. failure mode). An asset defect if left uncorrected will result in a functional failure of the asset in the future.	An asset defect is identified and raised against an asset master data record when the asset fails to meet the threshold criteria set to enable it to remain in working order until the next planned maintenance cycle. This transactional data is generated from inspections, testing and condition monitoring and is raised for the purpose of establishing future corrective maintenance activities that are undertaken to rectify the defect and return the asset to an 'as good as old' state before it functionally fails.
Asset Measurement Readings	One or more readings logged against an asset	An asset measurement reading is entered against an asset master data record and can be in the form of a volume of oil leaked, or a test result, amongst others.
Work Orders	Used to capture a task, activities, time, resources and expenditure in response to a job (e.g. asset failure or asset defects)	An asset work order could be created in response to an asset defect being created against an asset master data record to capture the activities, resources and costs in rectifying the issue.
Incident Data	Adverse events that occur on the network	This includes the recording of outages, fires, safety and environmental incidents, etc.

The term 'asset defect' for the purposes of this document represents an asset issue that if not corrected will result in a functional failure. This does not include all defects as there are many where minor maintenance activities may be required to support the ongoing management and risks of an asset but do not relate to asset degradation e.g. re-tensioning of low mains.

2.3 Rules

Rules have been developed to enable input data to be interpreted into asset CBA model inputs. These rules are used to establish the interrelationships between asset master data records and their associated transactional data. They are also used to group and aggregate assets into specific categories for future analysis and processing and to establish the data relationships and processes that accurately reflect the risks and benefits being used in this analysis.

For example, environmental risks such as oil spills are not applied to assets such as poles while safety risks such as being struck by a falling object are not applied to underground cables.

It must be noted for asset replacement investments the cause category (i.e. cause of the loss of control event) of 'asset' is isolated. Other cause categories such as nature, third party, people and process are not included.

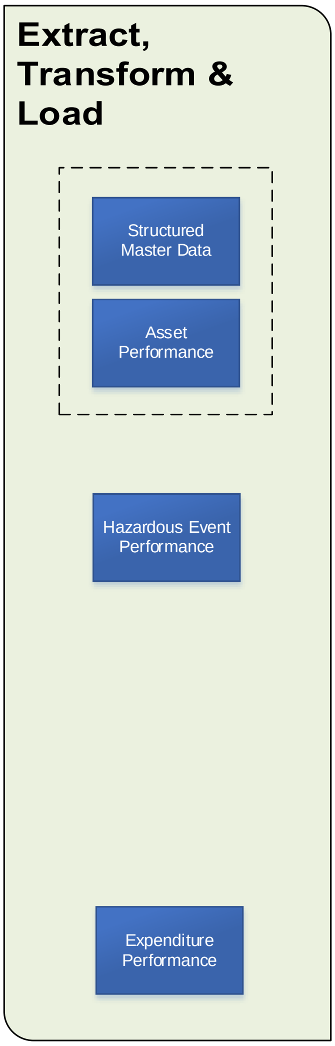
2.4 Value Dimensions and Metrics

Value dimensions (also known as consequence categories) and metrics are defined in the Customer Value Framework. Value dimensions are the broad categories into which economic value (benefits) can be allocated. Value metrics represent the tangible economic and non-tangible monetised impacts to the community (benefits and costs) that arise from network related events (for example, a network interruption or safety event). The value metrics are applied across the different value dimensions:

- Non-tangible benefits are generally represented by consequences avoided such as outages, fires, safety and / or environmental incidents, and
- Tangible benefits include avoided costs from unplanned work.

The asset CBA model applies all value dimensions against all value metrics to determine the level of investment required to optimise economic benefit and achieve the corporate, asset management and regulatory objectives.

3 Extract, Transform and Load



The extract, transform and load (ETL) process is used to structure and aggregate asset master data and associated performance information from various corporate source systems (input data). The input data is transformed into a centralised, consistent, and structured format that best informs asset risk-based decision making.

The key components and information used and created in the ETL process can be grouped into the following types:

- Structured master data,
- Asset performance,
- Incident performance, and
- Expenditure performance.

Section 8 provides additional detail on data integrity and the data structure used in the asset CBA model.

3.1 Structured Master Data

Master data sets from multiple systems are correlated so that each asset that passes through the model has the required key master data for analysis. For example, asset characteristic data found in SAP is related with geospatial information for the same asset in GIS. Individual assets with their associated master data are then grouped into asset sub-classes. These groupings are defined in the Rules (Section 2.3) and represent the logical combinations in which to forecast failures and generate accurate risk models.

3.2 Asset Performance

Asset failures and defects (transactional data) are correlated to the same asset sub-class as the master data to align analysis. For example, failures and defects on poles are related to the asset sub-class ‘poles’ so that analysis can be performed for all poles. A list of asset sub-classes can be found in Section 9.

3.3 Hazardous Event (Incident) Performance

Historical incidents such as safety or fire events are categorised by their asset type (i.e. asset sub-class), cause category, hazardous event(s), consequence category along with the severity. Given the analysis is used to support replacement decisions, only the incidents that are caused by the condition of an asset (i.e. ‘asset’ cause category) have been included in this analysis. Other cause categories include nature, third party, people and process.

For example, take a failure of a low voltage overhead conductor which resulted in live conductors on the ground. If a member of the public was to contact these conductors, the safety incident would be reported and recorded in the safety system as incident data. Table 3Table 3 shows how this data has been captured for an incident related to the hazardous event ‘contact with live fallen wires’.

Table 3: Example Incident Data Structure

Asset Sub-class	Cause Category	Hazardous Event	Consequence Category	Severity[3]
Overhead mains – LV	Asset	contact with live fallen wires	Public Safety	Minor

A full list of hazardous events included in the asset CBA model and their description are provided in Section 10. Incident performance is sourced from historical Ausgrid data.

To best represent the future performance, Ausgrid takes into consideration whether multiple hazardous events may occur from a single incident in the following ways:

Multiple Hazardous Events: A single incident may result in one or more hazardous events. For example, a wires down safety incident could result in a 'contact with live fallen wires' and 'struck by falling object' hazardous events. As a result, to avoid counting a single incident multiple times, the single incident may be apportioned across multiple hazardous event outcomes:

$$Incident\ count\ per\ hazardous\ event = \frac{1}{n} \leq 1$$

where n = number of hazardous event categories attributed to a single incident, and the incident count per hazardous event is always less than or equal to 1.

Treatment of Near Misses: A near miss represents a high potential incident (HPI) that could have resulted in a realised hazardous event. To reflect potential safety risks, near misses have been included in the analysis if there was a high potential that the failure of the asset could have injured a person. This approach recognises that just because something has not occurred yet, it does not mean that it never will occur. To avoid inflating the impact of near misses, they are considered within the analysis through the following method:

- All near misses are initially weighted with a 0.5 multiplier,
- Near misses are given a severity of insignificant, and
- Near misses are also given an additional weighting to cap the total contribution based on the number of realised incidents, so that:
  - The weighted contribution of near misses cannot exceed the total number of realised incidents, and
  - Where no realised incidents have been recorded the total contribution of near misses cannot exceed 1 incident.

All base year incident data used in the modelling is validated against historical incident performance to demonstrate reasonableness. For example, safety incidents are aggregated across all assets and compared against history both from a count by severity perspective and also from the perspective of 'years until event', particularly for major and significant incident severities.

3.4 Expenditure Performance

The avoidance of other expenditure through replacement of an asset is recognised as a benefit in the model, while the cost to replace an asset represents the cost to a customer. Expenditure is split into the following categories:

[3] Severity scale is only used for safety (worker or public) related incidents

Table 4: Expenditure Types

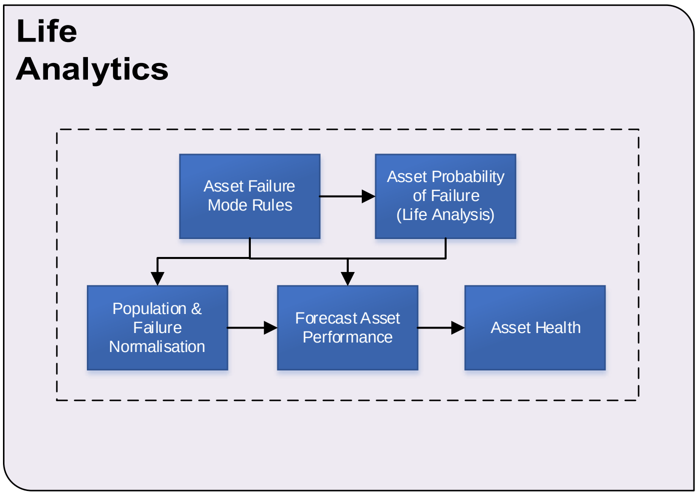
Expenditure Type	Asset Type Definition
Planned Investment	The planned replacement or refurbishment cost for the asset being modelled. This informs the cost used in the CBA.
Planned Maintenance	The cost to maintain the existing asset and the new asset being evaluated in the asset CBA model. Due to Ausgrid's condition-based maintenance approach, these costs are generally inspection costs. Where new asset technology has a lower maintenance cost than existing assets, this difference forms part of the benefit in the analysis.
Reactive Investment and Maintenance	The reactive costs, such as the cost to repair, refurbish or replace a defect or failure. The avoidance of these costs through investment, is a benefit in the asset CBA model.

When considering the impacts of these benefits, it is recognised that while expenditure will be avoided on some assets, it will increase for those remaining.

4 Life Analytics

Analysis of structured asset information is performed using statistical techniques for the purposes of:

- Undertaking life analysis to establish relationships between asset failures, characteristics, measurements, geospatial data and other information,
- Applying statistical techniques to generate failure parameters, and
- Forecasting the probability of failure over the life of the assets.



4.1 Asset Failure Mode Rules

This process is designed to filter only those failures modes associated with asset defects and failures that are appropriate for life modelling. Defects and failures are included if they meet the following criteria:

- The failure mode is related to degradation of the asset,
- It is a defect that would lead to a functional failure of the asset under a 'do nothing' (inherent) scenario (i.e. an avoided failure), and
- Only one defect is included for a single asset per financial year. If there are multiple defects raised in a single year, the highest priority defect is included.
- If a defect meets the above criteria, the remaining life (i.e. warning period) is estimated from the priority on the defect notification as per Table 5 below.

Table 5: Defect Priority and Remaining Life

Defect Priority	Estimated Remaining Life (Years)
Breakdown	0
Category 1	0
Category 2	0.25
Category 3	1
Category 4	2
Planned Date Range	5
Unrestricted	15
Not Assigned	15

4.2 Asset Probability of Failure (Life Analysis)

Life analysis establishes relationships between asset failures and characteristics, measurements, geospatial data and other information (asset information) for the purpose of generating individual asset failure parameters to predict asset failure rates / PoF. The key statistical techniques used to optimise this relationship for the asset CBA model are:

- Multivariable Regression, and

- Adjusted R-Squared Selection Regression.

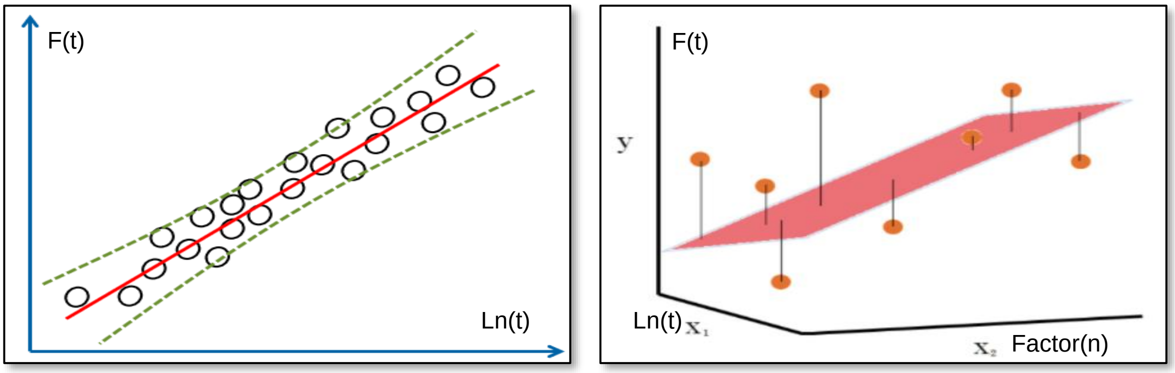
4.2.1 Multivariable Regression Model

The correlation technique used to establish the relationship between asset failures and the asset information for an individual asset within each asset sub-class is a multivariable regression model (**MVR** model). The key process steps in the MVR model are as follows:

1. Selection of asset information that could influence the PoF of an individual asset,
2. Derive the cumulative distribution function for each asset sub-class using the median rank methodology[4],
3. Calculate asset information weightings using multivariable regression analysis[5],
4. Calculate individual asset life parameters which are a function of the factor weighting values above by applying one of the correlation techniques shown in Table 6 to establish life parameters with the correlation technique used depending on the asset type, and
5. Calculate individual asset failure rates (PoF).

Figure 9 shows an example of a simple and multi-variable regression method. In this example, the simple method only looks at 2 factors, while the multi-variable considers 3 factors. The multi-variable analysis used in the modelling includes many more factors, however, only 3 are shown for simplicity.

Figure 9: simple (left) and multi-variable (right) regression methods



Including multiple factors in the analysis improves the accuracy of failure predictions, as generally asset deterioration is impacted by a combination of factors. Depending on the asset type, either a Weibull or modified Crow-AMSAA approach has been adopted as the analysis technique. These are both broadly accepted and widely used analysis techniques. A list of asset sub-classes and average parameters for the assets within each sub-class can be found in Section 9.

Table 6: Predictive modelling technique applied for different asset types

Asset Type	Analysis Technique
Discrete assets	Weibull[6]
Linear assets	A modified Crow-AMSAA approach, consistent with modern methods [7]

[4] Ebeling, C.E. 1997, *An Introduction to Reliability and Maintainability Engineering*. Chapter 12.2.3
[5] Hastie, Trevor, et al. *The elements of statistical learning: data mining, inference, and prediction*. Vol. 2. New York: springer, 2009
[6] Abernethy, R. 1996, *The New Weibull Handbook Second Edition*.
[7] Gill, Y. 2011, '*Development of an electrical cable replacement simulation model to aid with the management of aging underground electric cables*.', IEEE Electrical Insulation Magazine, vol. 27, January-February, no. 1, pp. 31-37.

The life parameters (β) influence the shape of asset degradation (rate of change). The β value is reviewed to validate whether the shape of asset degradation reflects those typical for the asset being modelled.

The life parameters (η in the case of Weibull and λ in the case of Crow-AMSAA) or scale parameters influence the overall magnitude / intensity of asset failure. The η and λ values are reviewed to validate whether the overall number of base year failures reflects those typical for the asset being modelled.

4.2.2 Adjusted R-Squared Factor Selection

In order to optimise the MVR model asset failure prediction (i.e. fit), each factor and combination of factors considered for a given asset sub-class are chosen based upon maximising the adjusted R-Squared outcome for the set of factors passing through the MVR model. The adjusted R-squared measures the proportion of variation explained by only the additional factors that materially improve the fit beyond what would be expected by chance. If eight factors (i.e. explanatory variables) were analysed for a particular asset group, a total of 255 combinations of factors are considered in optimising the fit in the MVR model with the chosen factors maximising the adjusted R-squared value. Table 7Table 7 provides an example for maximising the fit for a particular asset type with 4 factors, including age.

Table 7: Example Adjusted R-Squared for a Particular Asset Type

Asset Health Parameters	Number of Factors	Adjusted R-Squared
Age only	1	82%
Age, Distance to Coast, Insulation Type and Manufacturer	4 (chosen)	98%

The adjusted R-squared measures the proportion of variation explained by only the additional factors that materially improve the MVR model fit. Using this technique provides a level of validation of the historical data going into the MVR model and the failure parameters used to predict future failures.

4.3 Population & Failure Normalisation

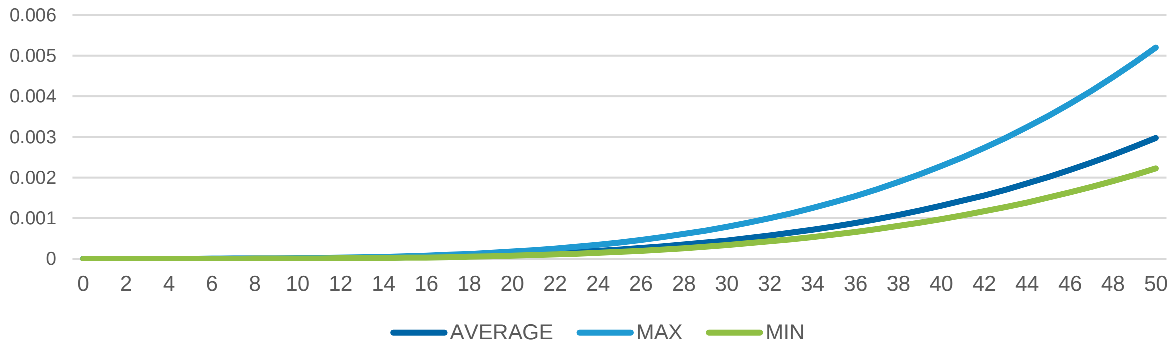
To ensure the life model reflects recent historical performance, the prediction is normalised to the historical asset performance. To do this, the average of the last 5 years of asset performance data is used to generate an average failure base year. The failure predictions are then normalised against this performance and adjusting the scale parameters (η and λ) so that the predicted number of failures in the first year (i.e the base year), reflects the 5-year historical average.

Failure normalisation to the average asset performance validates that the base year failures within the model reflect historical failures and historical avoided failures.

4.4 Forecast Asset Performance

Applying the methods described above produces failure curves for each individual asset within an asset sub-class depending on the selected asset health parameters. Figure 10 shows an example asset life characteristic for the worst (i.e. light blue), average (i.e. dark blue) and best (i.e. green) performing assets for a particular asset sub-class. The performance of an individual asset can therefore be predicted, at a given time, using the specific asset health parameters through this process.

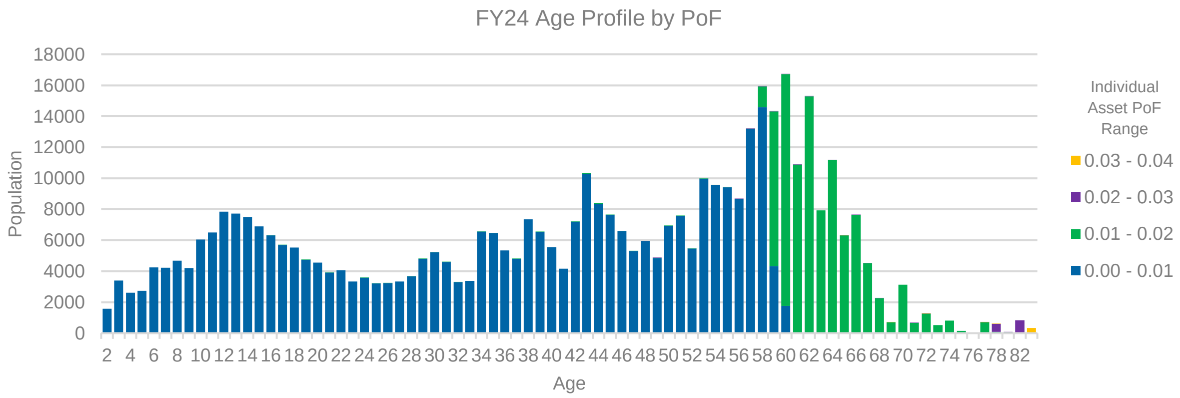
Figure 10: Example Asset Life Characteristics



4.5 Probability of Failure

The probability of failure for an entire sub-class can then be shown as it relates to asset age in any given year. **Error! Reference source not found.** shows the probability of failure for an asset sub-class and its age profile. In this example there is a strong relationship between the probability of failure and asset age as can be seen by the colours on the chart, with almost all assets less than 58 years of age having a probability of failure between 0 and 0.01.

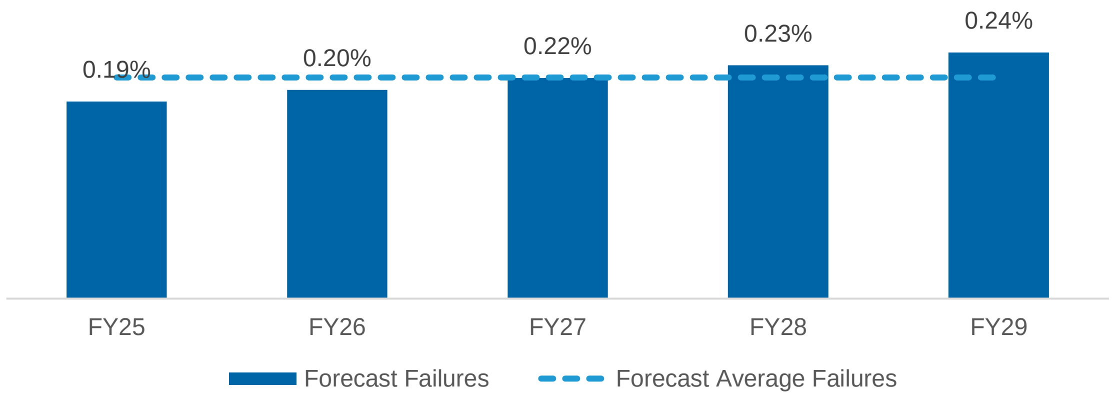
Figure 11: Asset sub-class health



In addition to understanding asset-class health from the perspective of the asset population age profile above, the base year failures and total forecast failures are represented as a percentage of the population to enable the assessment of the reasonableness of the failure forecast. Figure 12 below shows the forecast of inherent failures as a proportion of the population of Overhead Support Structures. As can be seen, the forecast average annual failures over the five-year window remains less than 1% of the population per year.

A forecast annual failure rate of 1% per year suggests that, if this failure rate was sustainable, these assets would reach 100 years life before replacement. The low failure rate in Figure 12 may suggest the failure rate being used is too low, however, this performance is backed by strong historical data and therefore considered the result of good asset management.

Figure 12: Forecast inherent failures as a proportion of population



As an additional validation of the failure forecasts, the base year failures are represented as a percentage (%) of the population to assess the reasonableness of the failure forecast.

5 Risk Assessment

While the probability of failure provides an indication of asset risk likelihood, it does not consider the associated consequences resulting from asset failures. To undertake an economic evaluation for a proposed investment, asset risk is monetised using the key principles of the equation in Figure 13.

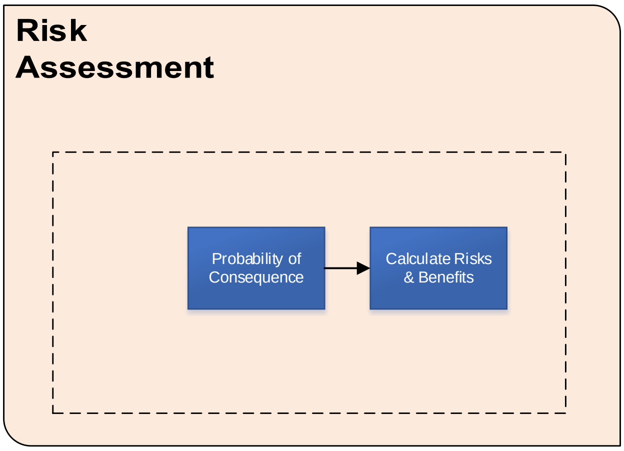
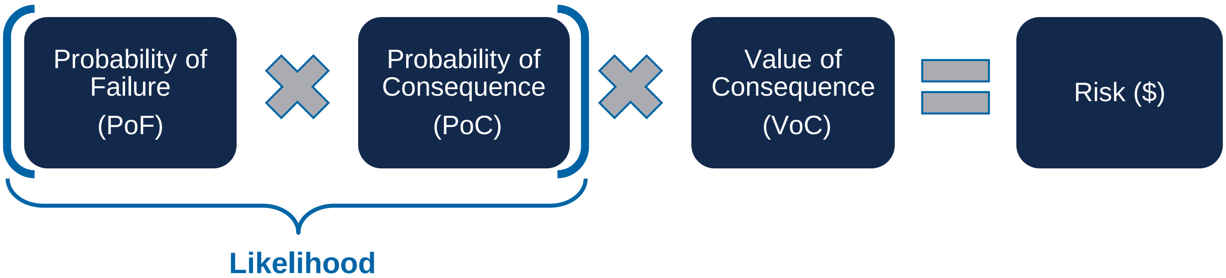


Figure 13: Monetisation of Asset Risk



The benefit associated with undertaking an investment to mitigate the risk is given by the equation in Figure 14. The ‘inherent risk’ is the risk posed by an asset before investment or without undertaking an investment (i.e. do nothing), the ‘residual risk’ is the risk posed by an asset following an investment.

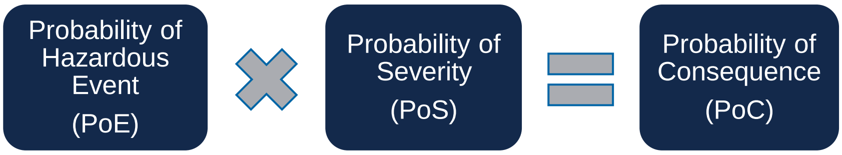
Figure 14: Monetisation of Economic Benefits

5.1 Probability of Consequence

This process combines the Structured Master Data, Asset Performance and Incident Performance to calculate the Probability of Consequence (PoC). The PoC consists of:

- the Probability of a Hazardous Event (PoE) being the probability that the hazardous event was realised if an asset failure was to occur, and
- the Probability of Severity (PoS) represents the probability of the scale of the consequence if the hazardous event was realised.

Figure 15: Probability of Consequence Calculation



Refer to Figure 6 for detail on the sequence of events that makes up the realisation of a consequence.

5.1.1 Probability of a Hazardous Event (PoE)

The probability of a hazardous event being realised (PoE) is based on the known recent performance for a given asset sub-class. To calculate this, the historical hazardous events under each consequence category and asset sub-class (as shown in the example in Table 3) are considered against the historical asset performance for that asset sub-class (realised asset failures) over the same period. This is calculated using the formula:

$$Probability\ of\ Event\ (PoE) = \frac{Average\ Hazardous\ Event\ Incidents\ p.a.}{Average\ Functional\ Failures\ p.a.}$$

The PoE represents the number of incidents for a given number of failures. This probability is based on actual experience and is applied as a constant probability to a changing failure rate to enable the prediction of incidents over time. Total failures and incidents are derived from the base year approach and currently do not change with time.

The various hazardous events that relate to each asset sub-class can then be summated to the consequence category, for example, summating all hazardous events that relate to Public Safety and the Overhead Mains – LV asset sub-class (refer to Table 8Table 3).

For hazardous events where a particular combination has not been realised over the historical performance period a PoE is calculated using the assumed incident rate from the PoS process in 5.1.2 below.

PoE's are validated as a % against likely outcomes for the given event. For example, it is highly likely an asset failure could result in an outage (PoE may be closer to 100%), however, the likelihood of a safety incident may be rare or unlikely (PoE may be closer to 0%).

5.1.2 Probability of Severity (PoS)

The Probability of Severity (PoS) is the probability that a realised consequence is of a particular severity (magnitude). Where an asset population has realised a hazardous event of a certain severity the PoS for that asset population is calculated using the formula:

$$Probability\ of\ Severity\ (PoS) = \frac{Average\ Incidents\ of\ a\ Specified\ Severity\ p.a.}{Average\ Hazardous\ Event\ Incidents\ p.a.}$$

Incident severities associated with hazardous events are categorised according to the cause category, hazardous event, consequence category and severity combination as shown in the example belowTable 8 for a 'contact with live fallen wires' hazardous event. The probability of severity is set at the hazardous event and consequence category, not at the asset sub-class level.

The PoS values for the severity combinations as shown in the example always summate to 100% (i.e. A%+B%+C%+D%+E%=100%). The severity levels are defined in the Customer Value Framework.

Table 8: Example Hazardous Event Probability of Severity Structure

Cause Category	Hazardous Event	Consequence Category	Severity	PoS Value
Asset	Contact with live fallen wires	Public Safety	Significant	A%
Asset	Contact with live fallen wires	Public Safety	Major	B%
Asset	Contact with live fallen wires	Public Safety	Moderate	C%
Asset	Contact with live fallen wires	Public Safety	Minor	D%
Asset	Contact with live fallen wires	Public Safety	Insignificant	E%

For hazardous events where a particular severity or severities have not been realised over the historical performance period an assumed incident rate is applied at the portfolio level which is determined through longer term historical performance and organisational expertise. Similar hazardous events are grouped together and the minimum incident rates by severity shown in Table 9 are considered as a basis for an assumed rate.

To not inflate risk at the portfolio level similar hazardous events are grouped together and the minimum incident rates by severity shown in Table 9 are applied as a basis for an assumed rate. For example similar hazardous events such as 'contact with live electrical equipment inadvertently energised' and 'contact with live fallen wires' are grouped together so that the aggregate assumed incident rate is consistent with Table 9 below i.e they would each have a significant severity of 1 in 200 years.

Table 9: Incident rate per severity where no realised incidents per severity have occurred

Severity	Assumed Incident Rate
Significant	1 in 100 years
Major	1 in 50 years
Moderate	1 in 20 years
Minor	1 in 5 years
Insignificant	1 in 2 years

To validate the appropriateness of the incident rates, a top-down check of the 'years until an event' for each severity is applied within each asset sub-class, asset class, and at the portfolio level by aggregating across all assets.

5.2 Calculate Risks & Benefits

Risks used to justify replacement investment are grouped into the following consequence category risk themes:

- Safety (worker and public),
- Loss of supply,
- Fire, and
- Environment.

The asset CBA model calculates these by undertaking the following sub-processes.

5.2.1 Safety Risk

As defined in the Customer Value Framework, a severity scale is used to represent different degrees of harm and a different monetised value of consequence (VoC) for each severity. This supports the notion that customers place a different value on risk depending on its severity. Figure 13 Figure 13and Figure 15Figure 15 can be applied for each severity and is calculated using the formula:

$$Risk\ per\ event\ (RpE_{HE})\ per\ severity\ (\$)\ = Asset\ PoF \times PoE \times PoS \times VoC$$

This calculation is performed and categorised according to the cause category, hazardous event and consequence category for each severity. A 'Grossly Disproportionate Factor' (GDF) is applied to the VoC value in accordance with the Customer Value Framework. The risk per event for all severities is calculated using the formula:

$$Risk\ per\ event\ (\$) = RpE_{HE} = Asset\ PoF \times PoE \times \sum_{severity=1}^{n} \{PoS_1 \times Voc_1 + \cdots + PoS_n \times Voc_n\}$$

The resulting risk across all potential hazardous event, cause and consequence categories is then calculated using the formula:

$$Risk_{SAFETY}\ (\$) = \sum_{HE=1}^{n} \{RpE_{HE\_1} + \cdots + RpE_{HE\_n}\}$$

Safety incidents are reviewed in terms of the 'number of incidents per year' and 'years until event' by severity level. All base year incident data used in the modelling is validated against historical incident performance to demonstrate reasonableness.

5.2.2 Loss of Supply Risk

The calculation of loss of supply risk in the asset CBA model does not apply a severity scale and relies on the Value of Unserved Energy ($VoUE$) as captured in the Customer Value Framework. As a result, loss of supply consequence is directly derived for each asset as the asset CBA model maps an individual asset to its network connectivity.

The steps involved in the calculation of the components of the loss of supply risk in the asset CBA model is as follows and as shown in Figure 16:

- Average individual customer power (energy) usage at the National Metering Identifier (NMI) level is obtained from 15 minute metering interval data (lived experience) over a full year.
- Weighted average restoration times (lived experience) per customer per network element (e.g. LV Distributor) per topology dimension (e.g. Local Government Area, LGA) using 5-year historical outage performance data.
- Value of Customer Reliability (VCR) per individual customer (NMI) by customer type and usage rolled up as a weighted average per individual network element (e.g. LV Distributor). The appropriate VCR values used are captured in the Customer Value Framework.
- The calculation of the VoUE is undertaken as described in the Customer Value Framework using the formula:

$$Value\ of\ Unserved\ Energy\ per\ Event = Average\ Restoration\ Time \times Avg\ Customer\ Power \times Customer\ VCR$$

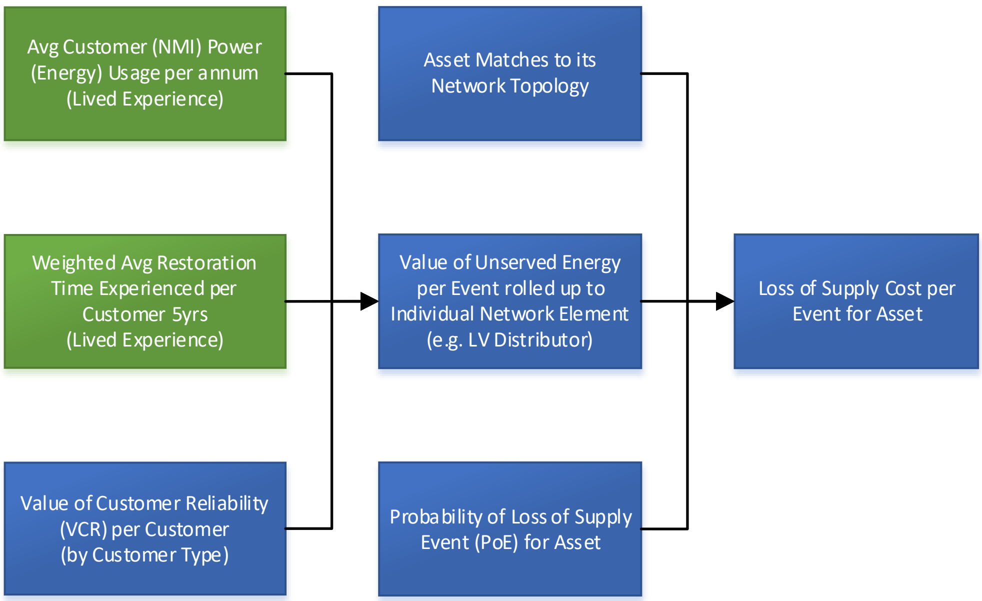
- The VoUE per event calculations above are rolled up from the customer level to the individual network element (e.g. individual LV distributor ID).

- The probability of a loss of supply event (PoE) for each asset sub-class is obtained using 5-year historical outage performance data. For asset replacement investments only the outage events where the asset is the 'cause' of the outage are used in the PoE calculation.
- Each individual asset matches to its associated network topology element enabling the loss of supply risk to be calculated using the individual asset probability of failure (PoF) using the formula:

$$Risk_{LOS}\ (\$) = Asset\ PoF \times PoE \times VoUE$$

This calculation is performed and categorised according to the cause category, hazardous event and consequence category combination. The PoE in the formula relates to a hazardous event that results in a supply interruption, most notably the hazardous event of 'loss of electrical continuity'.

Figure 16: Loss of Supply Process Steps[8]



5.2.3 Fire Risk

The calculation of fire risk passes asset information through the fire consequence model and is informed by the University of Melbourne (UoM) and the PHOENIX RapidFire Fire Simulator[9] fire consequence outcomes. This study determined the value of consequences at locations across the network applying a range of loss factors. For this analysis, the following loss factors have been included:

- Safety Consequences (life loss),
- Property Damage (house loss), and
- Environmental damage (plantation loss).

The consequences for individual assets are determined by their location and mapped to a common topology factor (i.e. postcode). They are represented by the loss per event (LpE) and the value of consequence for each loss factor. Fire risk is calculated using the formula:

[8] Green boxes indicated process steps based upon 'lived experience' and blue boxes highlight other process steps.
[9] Tolhurst K, Shields B, Chong D. 2008. Phoenix: Development and Application of a Bushfire Risk Management Tool. Australian Journal of Emergency Management, The 23:47-54

$$Risk_{FIRE}\ (\$) = Asset\ PoF \times PoE \times \sum_{LOSS\ TYPE=1}^{n} \{LpE_1 \times Voc_1 + \cdots + LpE_n \times Voc_n\}$$

The value of consequence (VoC) for these loss types is taken from the Customer Value Framework. For safety consequences (i.e. life loss) a GDF is applied. This calculation is performed and categorised according to the cause category, hazardous event and consequence category combination.

5.2.4 Environment Risk

Environmental risk has been categorised into four consequence drivers, each with their own monetised values:

- **Remediation Costs**: informed by the oil leaked into the environment in litres,
- **Greenhouse Gas Emissions**: the mass of greenhouse gas (GHG) emitted, and
- **Noise Impacts**: the average decibel (dB) over environmental requirements.

Environment risk is calculated using the formula:

$$Risk_{ENV}\ (\$) = Asset\ PoF \times PoE \times PoS \times VoC$$

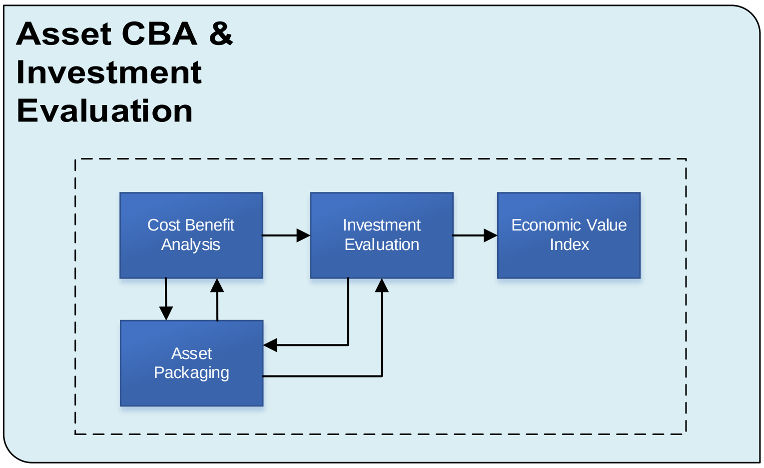
Where VoC differs for each of the consequence drivers and is defined in the Customer Value Framework.

5.2.5 Other Investment Benefits

Within this process other benefits are added to the risks avoided as shown in Figure 14Figure 14. These are split into financial benefits (avoided capital and operational expenditure) and technology change benefits.

- **Reactive Replacement Premium** for the additional costs incurred to reactively replace an asset after a failure instead of a planned replacement. This includes overtime costs and productivity costs due to diverting resources from other tasks,
- **Asset Repairs** for those proportions of situations where a repair is undertaken rather than a replacement after failure,
- **Operational Costs (OPEX) Avoided** includes a reduction in the annual OPEX (e.g. maintenance) for the existing asset compared to the new asset after investment. Operational costs avoided are determined as the difference between the current annual maintenance expenditure and the proposed annual maintenance expenditure for a given investment solution, and
- **Technology Benefits** includes where a particular risk or hazard is mitigated due to the design of the new technology. For example, where an oil insulated asset is being replaced with one that is air insulated, the environmental hazardous event is mitigated. This may also include technologies that provide real-time data for fault finding such as a built-in sensor and modem devices.

6 Asset CBA & Investment Evaluation



The Asset CBA and Investment Evaluation process takes the monetised risks and benefits and compares this to the cost of investment.

This process also allows evaluation of the 'higher level' asset. This evaluation compares whether greater economic benefit is achieved from replacing an entire asset which is made up of individual 'lower level' asset components (as part of the asset packaging process) as opposed to replacing the lower level asset components individually.

Finally, an Economic Value Index can be produced to show the CBA ratio for the entire population of assets within an asset sub-class.

6.1 Cost Benefit Analysis

Within this process the economic benefits for each asset calculated in Section 5 are compared to the annualised investment costs to produce a benefit to cost ratio (BCR). The BCR is calculated using the formula:

Figure 17: Benefit to cost ratio

The annualised investment cost is calculated by the Annual Deferral Benefit (ADB) realised for every year the investment is deferred. A one-year deferral benefit is calculated using the formula:

$$One\ year\ deferral\ benefit\ = p - \frac{p}{(1+r)}$$

where, $p = investment$ ($) and $r = discount\ rate$ (%)

The BCR represents economic value, and will result in one of the three following outcomes:

- BCR > 1 where the economic benefits exceed the cost of investment
- BCR = 1 where the economic benefits equal the cost of investment
- BCR < 1 where the cost of investment exceeds the economic benefits from that investment

6.2 Asset Packaging

The asset packaging process within the asset CBA model provides an opportunity to evaluate whether it is appropriate to package the individual lower level asset components into a 'higher-level' asset. The risks and benefits for the individual lower level asset components are derived using the processes described above and then aggregated to the higher-level asset. The BCR for the replacement of these individual assets may be lower than the BCR for replacement of the high level

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asset. This can be the result of the incremental cost for replacing all of these individual assets being lower than the incremental benefit gained by packaging them together. The aim of this evaluation is to maximise economic benefits by minimising multiple visits to the same location (i.e. the higher-level asset) to replace individual lower level assets. In situations where it is more economic to replace the higher level asset, double counting is avoided by filtering all the lower level assets out of the investment portfolio and only including them as part of the packaged higher level asset.

At this point, the outcomes of the analysis of the asset packaging process are not being adopted due to data maturity issues associated with the higher level asset that are resulting in inflated investment outcomes that are not consistent with organisational expertise.

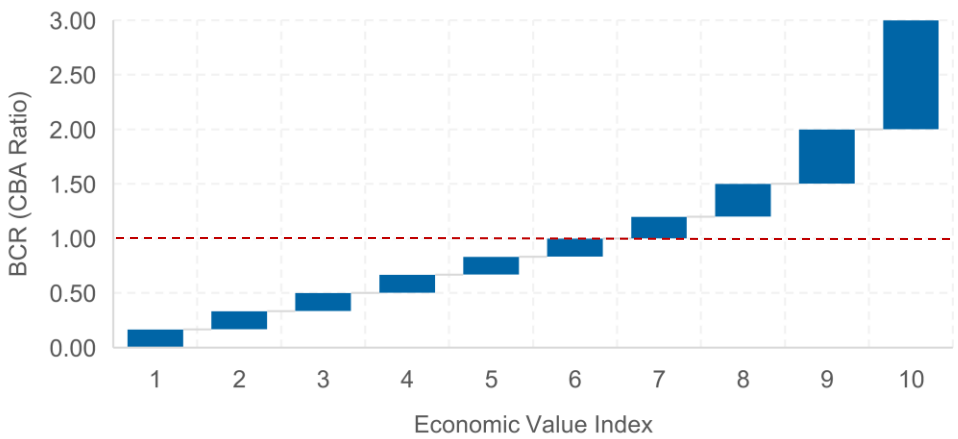
6.3 Investment Evaluation

In order for an investment to be considered prudent and hence appropriate to proceed, the economic benefits (including risk mitigated and any other benefits) from the investment must be greater than or equal to the annualised investment cost (i.e. $BCR \geq 1$). In other words, the benefits of the risk mitigated and any other benefits in undertaking the investment exceeds the annualised investment cost. This analysis is undertaken for each year in the forecast performance for each asset as risk changes with time.

6.4 Economic Value Index

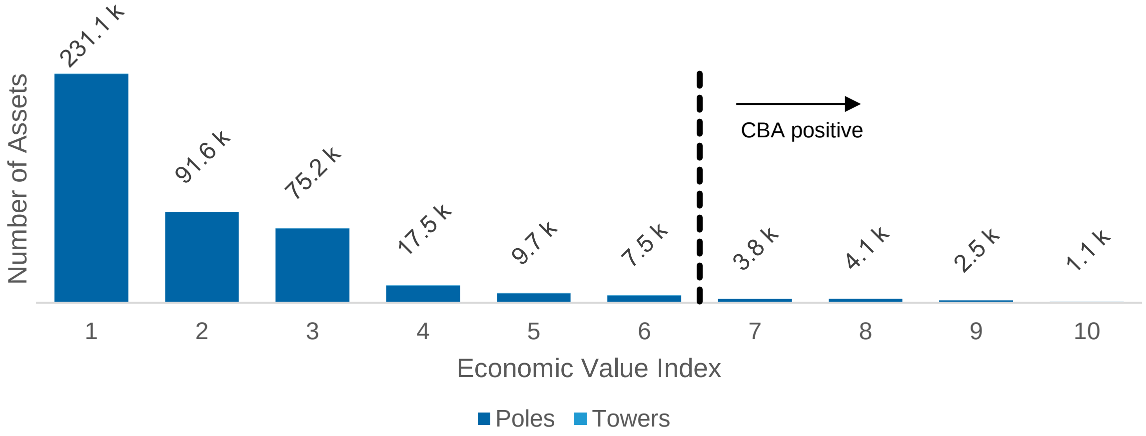
Similar to the approach applied to asset health, the BCR can be viewed across the asset sub-classes by applying an index based on the BCR range. This approach is used to visualise BCR across a population of assets. The relationship between the BCR and the risk index is shown in Figure 18Figure 18.

Figure 18: Example relationship between Economic Value Index and BCR



An example of the economic value index relative to the entire population within an asset sub-class is shown in Figure 19Figure 19. The population of assets with a BCR that supports investment can be seen by the volume with a BCR of 7 or above.

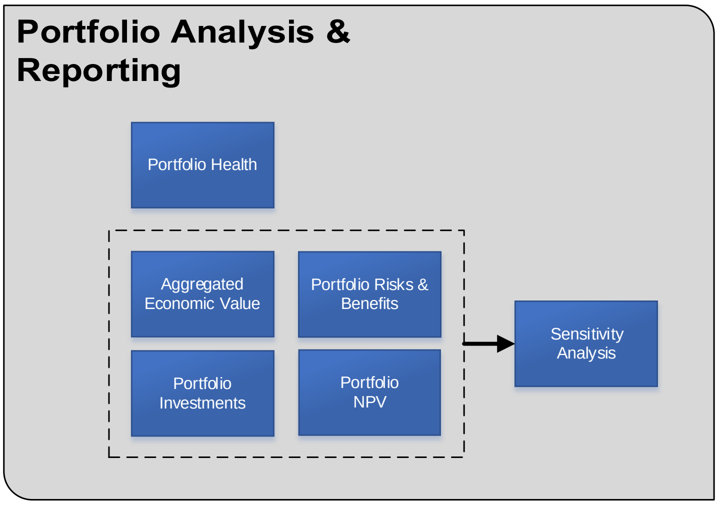
Figure 19: Example Economic Value Index



7 Portfolio Analysis & Reporting

An assessment of health, risk and benefits has been undertaken on individual assets, leading to an evaluation of investment. This has then been rolled up to an asset sub-class as shown in the asset health and Economic Value Index. These can be rolled up further to produce a view of health, risk and economic value across the portfolio of assets included in the analysis.

As the population of assets included in the asset CBA model increases, so does the coverage of the entire asset base.



7.1 Portfolio Health

Portfolio Health aggregates individual asset health, as shown in Figure 11**Error! Reference source not found.**, for all asset sub-classes to form a broader view of asset health across the population.

7.2 Aggregated Economic Value

The Aggregated Economic Value combines the Economic Value Index, as shown in Figure 19Figure 19, for all asset sub-classes to form a broader view of asset investment across the population.

7.3 Portfolio Investments

Based on the population of assets that have a positive CBA, a portfolio of investment is generated. This investment portfolio is determined by multiplying the investment unit rate by the population of assets with a BCR greater than 1. This analysis is repeated for every modelled year as risks and benefits change with time.

As the model is constructed from underlying failure rates, the analysis uses two assumptions:

1. Planned and condition-based replacement is fully effective in mitigating failures, and
2. Assets that fail are required to be replaced to provide customer services.

Applying these two assumptions results in the following outcomes when forecasting replacements:

- If the volume of assets with BCR $\geq$ 1 exceeds the annual forecast failures, the model is assumed effective and no additional volume is added to the portfolio to address failures, and
- If the volume of assets with BCR $\geq$ 1 is lower than the annual forecast failures, the replacement volume includes those with BCR $\geq$ 1 in addition to the incremental volume of expected failures not mitigated by planned and condition-based replacement.

The annual forecast failures considered to determine the incremental volume of expected failures (i.e. incremental reactive replacement volume) is found by applying the formula:

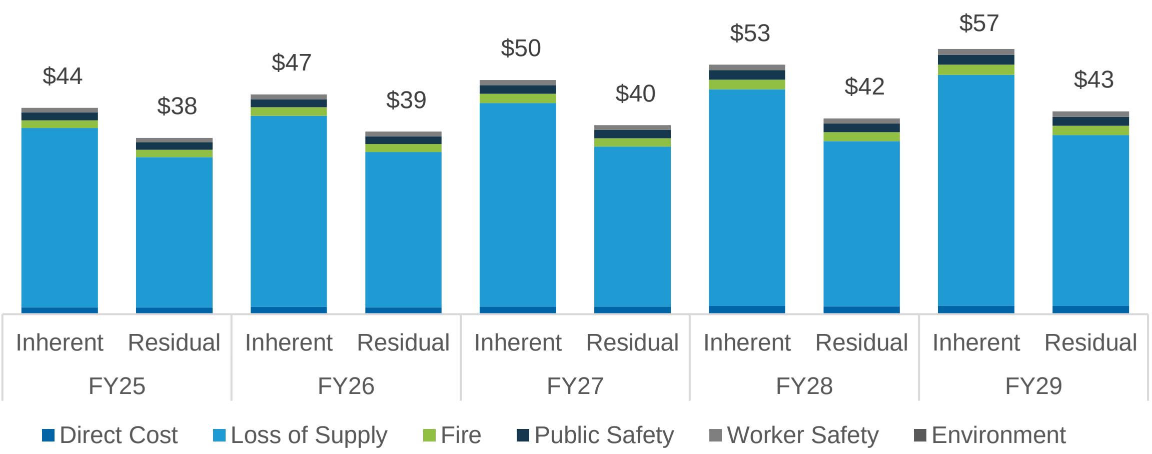
$$\begin{aligned}&Annual\ Forecast\ Failures\ to\ determine\ Reactive\ Replacement\ Volume\\&\qquad = Annual\ Forecast\ Failures\ x\ Historical\ Proportion\ of\ Failures\ Replaced\ (\%)\end{aligned}$$

In cases where an incremental reactive replacement volume is forecast the investment unit rate applied to this includes the reactive replacement premium as this incremental volume is assumed to be addressed in a reactive rather than planned fashion. Refer to the Customer Value Framework for details on the reactive replacement premium.

7.4 Portfolio Risks & Benefits

For each sub-class and across the entire population of assets included in the asset CBA model, the inherent risk and residual risk can be stacked by each monetised consequence category for each financial year as shown in Figure 20 for Overhead Support StructuresFigure 20. The inherent risk (left stack) and residual risk (right stack) is shown for each financial year.

Figure 20: Inherent and residual risk for Overhead Support Structures ($mill)



The inherent risk continues to grow as assets deteriorate and risk probabilities increase. The residual risk is informed by the change in risk based on the inherent risk growth and the risk removed following investment. The residual risk may increase or decrease depending on the level of growth in risk and the size of the investment.

This change in residual risk over time can be calculated using the compound annual growth rate (CAGR) formula:

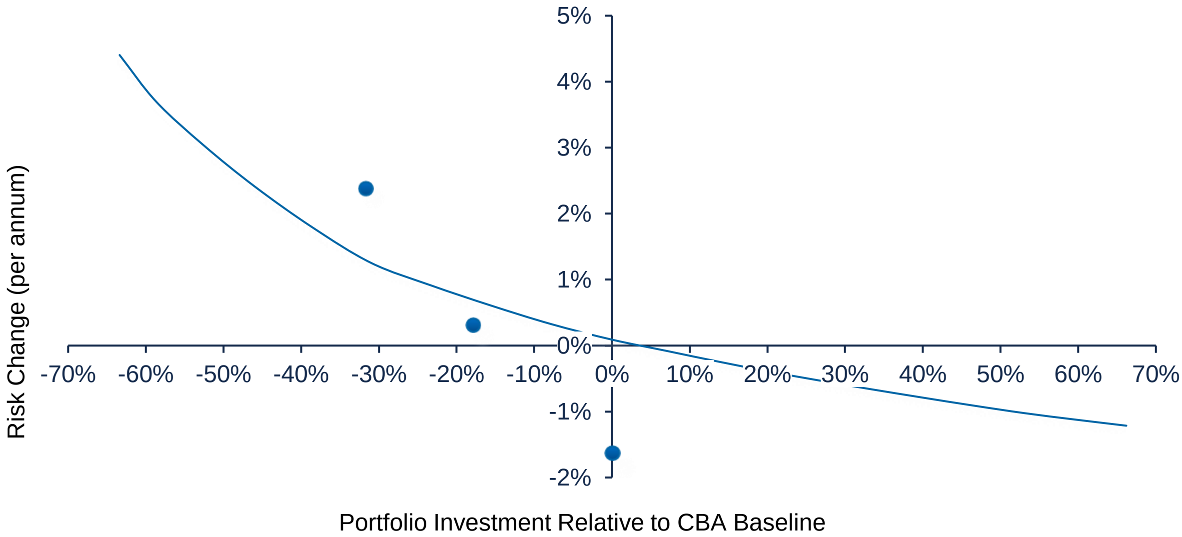
$$Risk\ CAGR \ = \left(\frac{Residual\ Risk_{Future}}{Residual\ Risk_{Initial}}\right)^{\left(\frac{1}{n}\right)} - 1$$

where, $n = time\ period\ in\ years$,

and $Risk\ CAGR$ is measured as the percentage change in risk per annum.

Sensitivity and scenarios can be established at a portfolio level by changing the investment and the resulting residual risk and risk growth outcomes can be demonstrated as shown in Figure 21. Depending on how the portfolio is defined for this analysis (e.g. total network in the case of Figure 21 or by asset class) will change the mix of potential investments and resulting risk growth outcomes for these scenarios. For example, the investment requirements to maintain risk at a total network level will potentially be different if risk was to be maintained at the asset class portfolio level.

Figure 21: Annual Program Expenditure vs Risk CAGR



The modelled portfolio outcomes shown in Figure 21 consider the forecast change in residual risk and investment up until FY29 only. In other words, each scenario (i.e. dot) is reproducing the portfolio inherent and residual risk stack as shown in Figure 20.

7.5 Portfolio Net Present Value

To support Ausgrid's approach to portfolio prioritisation, in addition to the annual deferral benefit calculation applied to the individual assets (see Section 7.3), Net Present Value (NPV) analysis is undertaken for each asset sub-class. This analysis is further sub-divided into three priority groupings for each sub-class:

- High (Economic Value Index 9-10),
- Medium (Economic Value Index 8), and
- Low (Economic Value Index 7)

The NPV is performed over a 30-year forecast period and considers the long-term benefits of the investment against the long-term cost. Using the three priority groupings enables portfolio prioritisation to be undertaken by these groups and asset sub-classes.

7.6 Sensitivity Analysis

Sensitivity analysis is undertaken to understand how sensitive the resulting portfolio of investments is to key asset CBA model parameters. Sensitivity analysis is used to establish the relative symmetry of the portfolio of investments to these changes. Sensitivity analysis is performed on the following items:

- Loss of supply consequence
- Near miss weightings
- Consideration of greenhouse gas emissions (i.e. SF6) and noise impacts within the environmental consequence
- Consideration of the environmental damage value metric of plantation loss within the bushfire consequence
- Grossly disproportionate factors
- Probability of failure
- Portfolio risk change, and
- Maintaining portfolio risk at the total network and asset class levels

8 APPENDIX A – Data Integrity and Structure

8.1 Introduction

The asset CBA model relies on asset data and historical performance data to predict future risks and inform investment decision making. Key input data to the model includes:

1. Asset population,
2. Asset technical / geospatial characteristics,
3. Historical asset condition test results,
4. Historical asset failure and defect data,
5. Historical expenditure data and unit rates, and
6. Historical incident (event) data.

The asset CBA model utilises key information to inform current and future asset risks. The accuracy of this data is therefore an important requirement to asset investment decision making. Several approaches are implemented to support data accuracy including:

- **System configuration** – Quality checks and controls are configured into Ausgrid's Information Management Systems to reduce the likelihood of poor-quality information being entered. This includes data entry validation and automatic population of derived data from standard construction types,
- **System integration** – Integration provides a way to automatically cross reference, detect duplicate data entry and report on information which may conflict, or not meet required quality standards. This includes cross-checking of data stored across multiple systems,
- **Manual observation** – When information is created it may also be manually verified against source documentation, observations and system records. Information is also verified against information specifications in user manuals, work instructions, asset maintenance and other information specifications. Work instructions specify to not only capture new information based on observations but also to verify master data information ensuring the information quality is continuously maintained to overcome previous potential collection errors,
- **Cross referencing** – Information quality is verified through data extraction and cross referencing manually or automatically from various data sources such as photos, Light Detection & Ranging (LiDAR), or externally obtained information, and
- **Automated validation** – Information is also checked by automated programs to validate its veracity, where possible. These programs include checks of the network connectivity model in the GIS, after new additions or changes.

We implement and maintain management systems and information systems required to ensure ongoing compliance with the Regulatory framework and licence conditions under which we operate as a Distribution Network Service Provider (DNSP).

8.2 Asset population

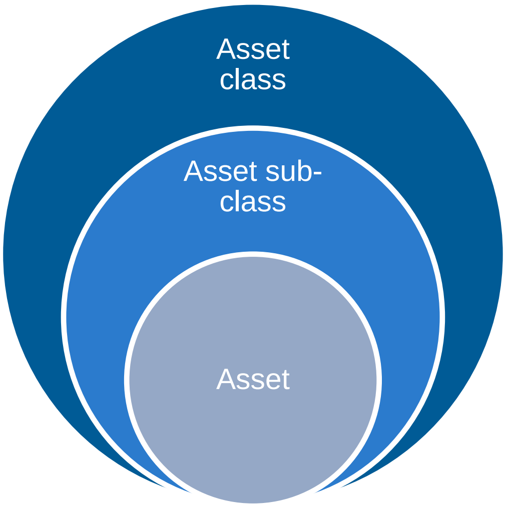
To understand the investment needs across the entire network, all assets need to be individually identified to complete a cost benefit analysis.

The definition of an 'asset' for the purposes of modelling is based on the lowest level of asset that can be managed through capital investment. For example, while a cross-arm is a component of a pole, we undertake cross-arm replacements as part of pole replacement and therefore each cross-arm is classified as an asset.

Asset management systems require asset records to be created before new assets or replacement assets are accepted onto the network. Assets are tracked as asset records across their life cycle from the stage when they are proposed and then commissioned into service, across their operational life and finally when they are disposed of.

For the purposes of modelling these individual assets are rolled up to an asset sub-class, for example cross-arms. These are then rolled into asset classes.

Figure 22: Asset data structure



Based on this mapping we have undertaken CBA modelling on more than 5 million assets, across 30 asset sub-classes and 6 asset classes (refer to Section 9) to gain a comprehensive view of comparative risk across the network.

8.3 Asset technical / geospatial characteristics

Within the asset management systems, key master data is captured against individual assets which provides unique information about the asset. Examples of master data include, but are not limited to:

- Date of installation / commissioning,
- Manufacturer and model,
- Asset design rating or strength,
- Construction material types,
- Operational detail,
- Physical location, and
- Network connection details.

Different technical and geospatial characteristics may result in different asset performance outcomes and this is therefore critical in determining asset risk. Key technical characteristics are used to inform the 'inherent strength' of an asset while geospatial characteristics generally inform the 'typical stresses' an asset experiences through its life. For example:

- an exposed overhead conductor near the coast may deteriorate faster than an insulated overhead conductor away from the coast due to the exposure of the metallic conductor to the more corrosive coastal environment.

In this example the construction of the conductor (technical characteristic) and its proximity to coast (geospatial characteristic) impacts its overall performance.

8.4 Historical asset condition test results

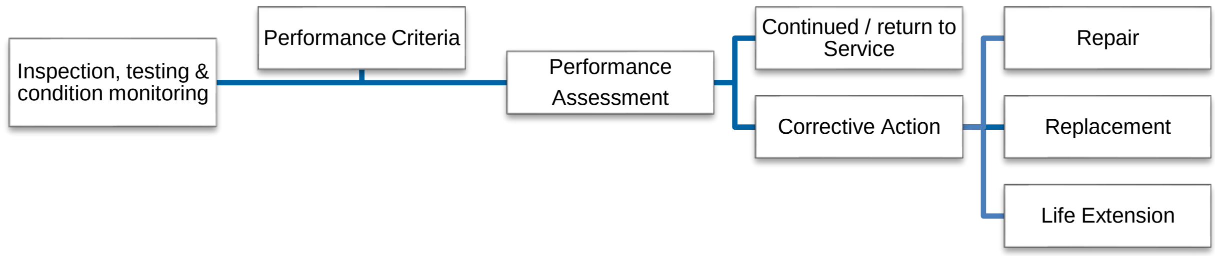
While asset characteristics provide a basis for informing inherent strengths and stresses to assets, asset deterioration leads to a reduction in asset strength over time.

While asset age generally has a strong correlation to asset condition, other condition information may be collected through inspections, condition-monitoring and testing. Ausgrid's condition-based maintenance (CBM) approach relies on the capturing of condition information from:

- Visual examination and assessment,
- Measurements, and
- Test results

Figure 23Figure 23 illustrates the process for undertaking CBM. Inspections, condition monitoring, measurement and testing is performed to understand the current condition of each asset and its ability to perform its function. The results are then assessed using serviceability criteria to determine if the asset meets its required performance criteria.

Figure 23: Condition Based Maintenance Approach



Field-based online forms have been developed to confirm maintenance activities are being undertaken and to capture key condition information including results from asset maintenance. The field-based online forms feed input and output information back to the information systems. As described previously, data-entry validation drives accuracy by limiting the ability to close out inspection activities without capturing all required information.

8.5 Historical asset failure and defect data

Service criteria limits are defined within Standards and set the warning period from when an asset defect is first identified to the point of asset functional failure. A defect is defined as the point at which an asset no longer meets its serviceability criteria. At this point the asset is approaching functional failure and is likely to fail unless intervention is undertaken. For example:

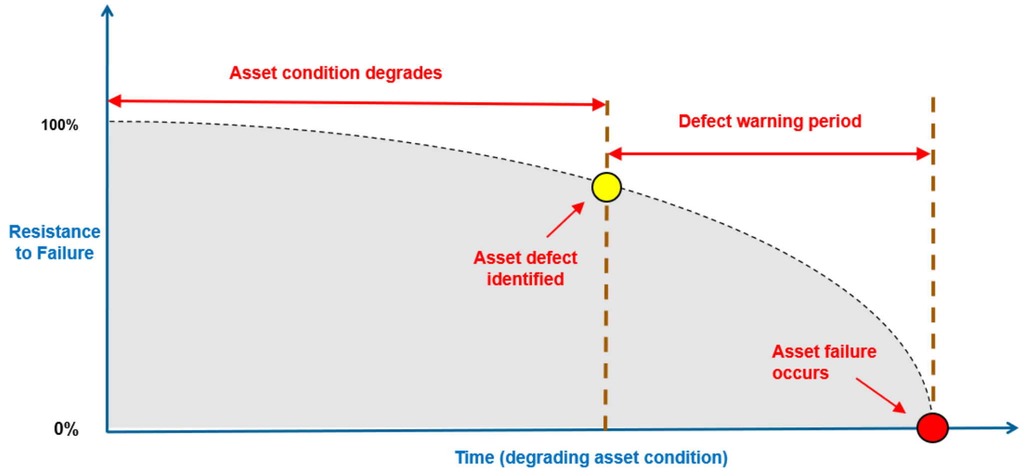
- the structural integrity of a pole has exceeded acceptable measurement limits (service criteria) however the pole has yet to fail.

A failure on the other hand is defined at the point at which an asset is no longer able to perform its function. For example:

- the function of a pole is to support conductors to achieve safety clearance from the ground. When a pole functionally fails, the pole is no longer able to achieve this function and the conductor is likely to breach vertical safety clearances.

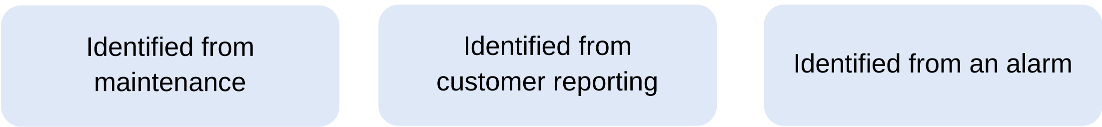
Serviceability criteria limits set the warning period to provide adequate time to identify and rectify defects before a functional failure is realised as shown in Figure 24Figure 24.

Figure 24: Asset resistance to failure



Asset failures and defects may be identified from a range of triggers:

Figure 25: Triggers for identifying failures and defects



Asset defects or failures can be identified by Ausgrid staff undertaking maintenance, reporting by customers and the public, and also from automated alarm systems which monitor network assets. Once identified, a record of the defect or failure is created within asset information systems with key failure information captured such as the mechanism or failure mode, the time the defect was found and the time remaining to rectify the defect before likely functional failure.

From this defect or failure record a work order is generated to provide a mechanism in which to capture resource information including labour, contracted services and materials.

The defect or failure and associated work order are required for field staff to capture their time against and therefore are a critical step in rectifying asset issues.

8.6 Historical expenditure data and unit rates

A work order provides a view of historical resources used to rectify a defect or failure. These resources are represented as a cost against the rectification activity which in turn is used to inform unit rates for future activities including repair, refurbishment and / or replacement.

Additionally, the cost associated with inspection and testing is also captured on individual work orders per activity through the booking of resources to individual jobs.

These costs form part of the cost benefit analysis trade-off as avoided inspections, repairs or reactive replacements are traded-off against the cost of investment through planned refurbishment or replacement.

8.7 Historical incident (event) data

In addition to the cost benefits, indirect benefits are also realised through planned capital investment, including:

- Avoided customer interruptions,
- Avoided safety incidents,

- Avoided environmental incidents, and
- Avoided fires.

Historical incident (event) data is used to inform the level of risk carried by each asset, which may be avoided if assets are replaced before reaching functional failure.

Asset incidents can be identified by Ausgrid staff undertaking maintenance, reporting by customers and the public, and also from automated alarms which monitor network assets in the same way that asset defects or failures are identified. The consequences of a defect or failure are recorded as an incident when service criteria limits are exceeded. An individual incident may be recorded in multiple management systems depending on the consequences. For example, when a pole functionally fails and results in wires lying on the ground and an interruption to the supply to customers:

- an incident is immediately recorded in the outage management system for the initial emergency response,
- an incident is recorded for the pole failure in the asset management system, and
- an incident is recorded in the safety management system due to the public safety risk associated with the pole falling down and wires on the ground.

As part of developing the asset CBA model, historical incidents were reviewed and classified into 35 hazardous events. For example:

- For a public safety incident where a customer received a shock from touching a tap in their home the incident was classified as a ‘domestic shock’ hazardous event and was found to be due to the failure of a connection on a service wire.

9 APPENDIX B – Asset Sub-Class & Class List

The following table is the list of the 30 asset sub-classes in alphabetical order and the associated asset classes used by the asset CBA model.

Asset Sub-class	Asset Class
AFLC	Communications, Control & Protection
Batteries	Communications, Control & Protection
Comms, Control & Protection - Protection	Communications, Control & Protection
Comms, Control & Protection - SCADA	Communications, Control & Protection
Overhead Mains - HV	Overhead Mains
Overhead Mains - LV	Overhead Mains
Overhead Mains - Service	Overhead Mains
Overhead Mains - Streetlighting	Overhead Mains
Overhead Mains - TR	Overhead Mains
Pole Top Structures	Overhead Support Structures
Poles	Overhead Support Structures
Switchgear - HV Breaker	Switchgear
Switchgear - HV Switch - Ground (Fuse Switch/RMU)	Switchgear
Switchgear - HV Switch - Ground (I&E)	Switchgear
Switchgear - LV Breaker	Switchgear
Switchgear - LV Switch - Overhead	Switchgear
Switchgear - TR Breaker	Switchgear
Switchgear - TR Switch - Ground (I&E)	Switchgear
Switchgear - TR Switch - Overhead	Switchgear
Towers	Overhead Support Structures
Transformers & Reactors - Distribution - Ground	Transformers & Reactive Plant
Transformers & Reactors - Distribution - Pole	Transformers & Reactive Plant
Transformers & Reactors - Instrument	Transformers & Reactive Plant
Transformers & Reactors - Power	Transformers & Reactive Plant
Underground Cables - HV	Underground Cables
Underground Cables - LV	Underground Cables
Underground Cables - Service	Underground Cables
Underground Cables - TR	Underground Cables
Underground Equipment - LV/HV Terminations	Underground Cables
Underground Equipment - Pillars & Pillar standards	Underground Cables

10 APPENDIX C – Hazardous Event List

The following table provides a list of hazardous events and a description of each, as well as whether it has been included as an input to the asset CBA model.

Hazardous Event	Hazardous Event Description	Included
compliance breach	A breach of a compliance requirement.	
contact with live electrical equipment inadvertently energised	An event where an asset, or part of an asset that would not normally be energised becomes energised.	✓
contact with live fallen wires	An event where overhead conductors breach minimum safety clearances, are still energised and a person may contact them.	✓
customer escalation	Customer complaints arising from an adverse experience with Ausgrid as a service provider (including voltage, supply quality and public lighting complaints)	
domestic shocks	An event within a customer's premises where a person has received a shock from an object that would not normally be energised (e.g. tap or shower head).	✓
emission of greenhouse gas into the atmosphere	An event resulting in a greenhouse gas leaking into the surrounding airspace.	
entrapment or entanglement	An event where a person becomes entrapped or entangled in an Ausgrid asset or construction site (e.g. falling into cable trench).	
exposure to arc flash	An event resulting in an electrical arc discharging through the gap (air) between two or more points producing a potentially significant amount of light, heat and even a shockwave.	✓
exposure to biological hazard, flora & fauna	An event where a person becomes exposed to a biological hazard from either flora or fauna (e.g. snake or dog bite, contact with bats and their biological hazards).	
exposure to contaminated land	An event where a person becomes exposed to hazards due to contaminated land.	
exposure to enclosed space / depletion of oxygen	An event where a person is exposed to a restricted work space and / or depleted levels of (life sustaining) oxygen.	
exposure to excessive EMF and RF	An event where a person is exposed to significant levels of electromagnetic frequency (low frequency) or radio frequency (high frequency).	✓
exposure to excessive asset noise	An event where a person is exposed to the sound produced by an asset exceeding certain loudness (decibel) levels.	
exposure to excessive construction noise	An event where a person is exposed to excessive levels of noise generated from construction activities.	
exposure to hazardous atmosphere	An event where a person is exposed to a hazardous atmosphere (e.g. SF6 gas, lead dust).	✓
exposure to hazardous chemicals and materials	An event where a person is exposed to chemicals and materials which are hazardous to human health.	✓
exposure to uncontrolled release of a pressurised substance (gas / fluid / air)	An event where a person is exposed to an uncontrolled release of a substance that is normally stored or operated under pressure.	✓
fall from heights	An event where a person has fallen from a height.	✓

Hazardous Event	Hazardous Event Description	Included
fire starts	An event where a flammable or combustible material is exposed to a heat source or high ambient temperature and starts a fire.	✓
leak, spill or discharge of a contaminating substance into the environment	An event where a contaminating substance (e.g. oil, liquid, gas) has leaked, spilled or been discharged into the environment from an Ausgrid asset.	✓
loss of electrical continuity	An event where the continuity of electrical supply is disrupted.	✓
make contact with overhead assets	An event where a person, vehicle or plant contacts Ausgrid overhead assets which are functioning normally.	
make contact with underground assets	An event where a person, vehicle or plant contacts Ausgrid underground assets which are functioning normally.	
other minor event not categorised	Other uncommon or minor events that are not categorised.	
slip, trip or fall	An event involving a person slipping over, tripping over or falling down.	✓
struck by expelled object	An event where a person or object is struck by an object forcefully expelled.	✓
struck by falling object	An event where a person or object is struck by an object falling from a height.	✓
struck by moving vehicle/plant or equipment	An event where a person or object is struck by a vehicle, plant or equipment.	
unauthorised access to the network (cyber)	An event where a person gains unauthorised cyber access to Ausgrid's information, communication and technology network.	
unauthorised access to the network (physical)	An event where a person gains unauthorised physical access to the electrical network and infrastructure.	✓
unauthorised harm to heritage or ecology	An event where unauthorised or unplanned harm or damage is inflicted on a heritage or ecological item.	
undertaking manual task	An event resulting in harm to a person undertaking a manual task (e.g. racking a circuit breaker).	
vehicle/plant accidents	An event where a vehicle or plant contacts another vehicle, plant or stationary object.	
vehicle/plant/public impact with asset (ground level)	An event where a vehicle, plant or person contacts an Ausgrid asset at ground level (e.g. pillar, kiosk etc).	

11 APPENDIX D – Model Parameters

The following table provides a list of the average failure parameters for the assets within each asset sub-class.

Asset Sub-class	Asset Type	Statistical Distribution	Beta (β)	Eta (η)	Lambda (λ)
AFLC	Discrete	Weibull	2.60	43.21	
Batteries	Discrete	Weibull	3.89	30.11	
Comms, Control & Protection - Protection	Discrete	Weibull	2.42	93.99	
Comms, Control & Protection - SCADA	Discrete	Weibull	3.00	25.80	
Overhead Mains - HV	Linear	Crow-AMSAA	2.87		2.75E-05
Overhead Mains - LV	Linear	Crow-AMSAA	3.59		8.30E-05
Overhead Mains - Service	Discrete	Weibull	2.84	79.74	
Overhead Mains - Streetlighting	Linear	Crow-AMSAA	3.55		1.19E-06
Overhead Mains - TR	Linear	Crow-AMSAA	4.71		7.29E-07
Pole Top Structures	Discrete	Weibull	4.17	147.22	
Poles	Discrete	Weibull	4.64	106.43	
Switchgear - HV Breaker	Discrete	Weibull	2.01	31.62	
Switchgear - HV Switch - Ground (Fuse Switch/RMU)	Discrete	Weibull	2.73	54.16	
Switchgear - HV Switch - Ground (I&E)	Discrete	Weibull	3.55	85.81	
Switchgear - LV Breaker	Discrete	Weibull	2.56	32.60	
Switchgear - LV Switch - Overhead	Discrete	Weibull	2.74	114.54	
Switchgear - TR Breaker	Discrete	Weibull	2.15	50.85	
Switchgear - TR Switch - Ground (I&E)	Discrete	Weibull	1.94	51.72	
Switchgear - TR Switch - Overhead	Discrete	Weibull	2.09	29.97	
Towers	Discrete	Weibull	7.78	75.81	
Transformers & Reactors - Distribution - Ground	Discrete	Weibull	2.94	62.03	
Transformers & Reactors - Distribution - Pole	Discrete	Weibull	3.04	88.65	
Transformers & Reactors - Instrument	Discrete	Weibull	2.27	48.23	
Transformers & Reactors - Power	Discrete	Weibull	3.78	42.56	

Asset Sub-class	Asset Type	Statistical Distribution	Beta (β)	Eta (η)	Lambda (λ)
Underground Cables - HV	Linear	Crow-AMSAA	3.04		1.84E-05
Underground Cables - LV	Linear	Crow-AMSAA	5.32		1.64E-08
Underground Cables - Service	Discrete	Weibull	3.00	191.29	
Underground Cables - TR	Linear	Crow-AMSAA	5.01		3.93E-08
Underground Equipment - LV/HV Terminations	Discrete	Weibull	3.00	112.38	
Underground Equipment - Pillars & Pillar standards	Discrete	Weibull	2.28	110.26	