Repex Risk Modelling

Model Framework

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SA Power Networks

Empowering South Australia

Contents

Glossary

Acronym / term	Definition
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
Augex	Augmentation expenditure
BCR	Benefit Cost Ratio
Capex	Capital expenditure
CBRM	Condition Based Risk Management
CER	Customer Energy Resources
COC	Cost of Consequences
DNSP	Distribution Network Service Provider
EDC	Electricity Distribution Code
EPA	Environmental Protection Agency
ESCoSA	Essential Services Commission of South Australia
ETC	Electricity Transmission Code
LOC	Likelihood of Consequences
NEL	National Electricity Law
NEM	National Electricity Market
NER	National Electricity Rules
NEO	National Electricity Objective
PLEC	Powerline Environmental Committee
POE	Probability of Exceedance
POF	Probability of Failure
POS	Probability of Severity
QoS	Quality of Supply
RCP	Regulatory Control Period
SAIDI	System Average interruption Duration Index
SCS	Standard Control Services
UK	United Kingdom

1 Introduction

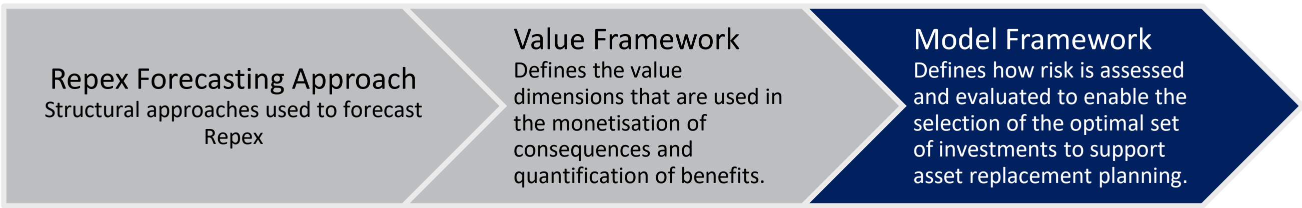
This document sets out details of SA Power Networks' Model Framework which has been developed to define the functional characteristics of SA Power Networks' replacement capex forecasting models.

1.1 Purpose

The Model Framework is one of two documents that together enable the selection of the optimal set of investments in support of asset replacement planning.

It is intended to define how risk is assessed and evaluated to enable the selection of the optimal set of investments to support long term asset replacement planning. It does this by calculating risk in monetary terms and optimising the set of investments applied to the asset base to maximise net economic benefits while meeting the risk, budget and operational constraints set by SA Power Networks.

Figure 1 – Forecast framework



1.2 Scope

Replacement expenditure forecasts will be based on a combination of actual historical expenditure for some asset classes, modelled forecasts for other asset classes where sufficient data is available and business cases for targeted/individual projects. This document describes the replacement capex forecasting approach for modelled asset classes. While the framework described in this document may be applicable, in part or in whole, to other expenditure areas within SA Power Networks, it has not been fully developed for these uses.

It is envisaged that over time, all asset replacement investments made by the organisation will be valued using the model methodology contained within this Model Framework.

1.3 Objectives

The objective of the Model Framework is to document a methodology for forecasting asset replacement expenditure. This includes forecasting for internal uses and for forecasts provided to the AER as part of a regulatory revenue submission.

The Model Framework must be compatible with the AER's guidance on asset replacement planning and should be comparable with the forecasting approaches used by SA Power Networks' peers in their submissions to the AER.

2 Model Development

2.1 Regulatory Requirements

The specification of SA Power Networks' Model Framework is guided by the need to align with regulatory rules, guidelines and expectations. In the regulatory context, the Model Framework supports the development of an efficient and prudent investment portfolio that maximises the benefits to customers.

The Australian Energy Regulator (**AER**) *Industry practice application note for asset replacement planning*[1] (the ARP note) is the key source of regulatory requirements for asset risk (benefit) modelling. Investment programs supported by modelling that is consistent with the approaches in the ARP note are therefore aligned to the requirements specified by the AER and the forecast capital expenditure objectives outlined in the National Electricity Rules (**NER**).

The AER *Better Resets Handbook*[2] provides guidance on capital expenditure forecasts for regulatory submissions and includes the latest guidance on the AER's expectations. The AER expects forecasts for total capital expenditure to be not materially above recent historic expenditure levels. Any increase will be considered in the context of network performance measures (such as the System Average interruption Duration Index - **SAIDI**) and may be rejected if the AER is not provided sufficient evidence that the network cannot maintain performance levels without the increase.

The AER will treat current period allowances as a revealed efficient expenditure level, subject to network performance measures being satisfactory. If a network forecasts a step up from such a level, a strong argument backed by modelling will be required to achieve AER approval.

There are circumstances where the AER recognises a business' actual total capital expenditure is a less useful top-down test of the forecast. This includes where capital expenditure is predominately made up of large non-recurrent projects or where a capital efficiency sharing scheme is not in place. Where this is the case, the AER expects networks to provide quantitative cost benefit analysis to demonstrate that the major project/programs driving the total forecast maximises net benefits.

2.2 Principles

The development of this model framework is informed by the AER's guidance note on asset replacement planning and uses a bottom-up modelling methodology.

The model framework is intended to produce forecasts that reflect the prudent and efficient operation and management of the electricity network while maintaining compliance with all applicable laws, regulations and industry standards.

The model framework also enables estimates of any increased or decreased operating and maintenance costs associated with forecast asset replacements. If material, this may result in a step change adjustment to our forecast opex.

2.3 Alignment with Corporate Risk Management Framework

The model framework provides the means of translating the risks identified in the Value Framework into investment decisions and budget forecasts that reflect the economic value of those risks. The Value

[1] AER, *'Industry practice application note for asset replacement planning'*, 25 January 2019, available via [www.aer.gov.au/industry/registers/resources/reviews/industry-practice-application-note-asset-replacement-planning], last accessed 25 January 2024.

[2] AER, *'Better Reset Handbook'*, December 2021, available via [www.aer.gov.au/documents/better-resets-handbook-december-2021], last accessed 25 January 2024.

Framework is aligned with the Corporate Risk Management Framework, so by applying the Value Framework, the Model Framework is also aligned to the Corporate Risk Management Framework.

3 Model Framework

The following sections describe the Model Framework to be used for the forecasting of asset replacement expenditure.

3.1 Overview

This Model Framework describes a model for forecasting asset replacement investments over time. The model produces replacement forecasts at an annual frequency and each year's forecast is based on the asset replacements that were forecast in all previous years.

The model framework has the following major sections:

- **Risk –** this section describes how the model calculates the risk associated with each individual network asset.
- **Asset Condition and Deterioration –** this section describes how the model applies changes to the condition of assets over time to reflect the expected degradation that will occur or expected asset condition improvement due to investment.
- **Investment Evaluation –** this section describes how the model evaluates and ranks all possible asset investments.
- **Investment Plan –** this section describes how the model selects investments that will be undertaken based on the investment evaluations and any binding constraints.
- **Forecasting Over Multiple Time Periods –** this section describes how the model transitions over forecast years.

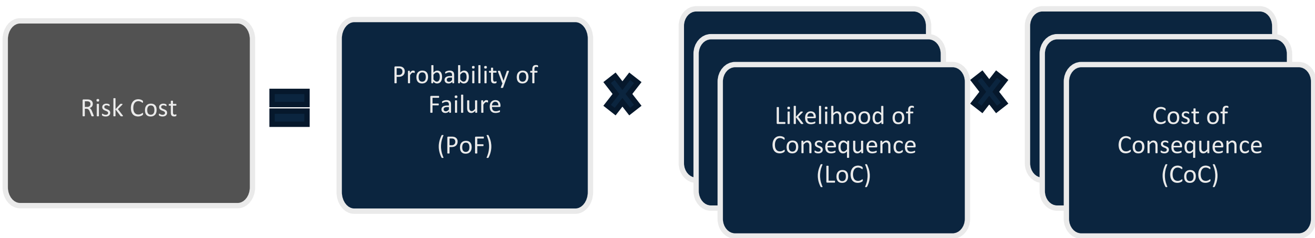
3.2 Risk

The most common driver of the replacement of network assets is condition deterioration leading to the failure of the asset. On failure, an asset may pose a risk to members of the public, network workers, the network itself or any other stakeholder in the electricity system.

The risk module calculates the risk for all currently installed assets under both no investment and post-investment scenarios for all assets that are entered into the model. This information is required by the Investment Evaluation module.

This is summarised by the Risk Cost, which is a measure of the expected financial (or monetised) value of the risk event. The high-level formula for calculating the Risk Cost is depicted in Figure 2.

Figure 2 - High Level Risk Framework



At its highest level, the Risk Cost is made up of three components defined as follows:

- **Probability of Failure (PoF)**: the probability that an asset experiences a non-repairable[3] functional failure during a given year.
- **Likelihood of Consequences (LoC)**: the probability that any given non-repairable functional failure of an asset results in a consequence occurring.
- **Cost of Consequences (CoC)**: the average cost of a consequence that results from the asset failure.

SA Power Networks' Value Framework divides risks into seven value dimensions, which are each monetised using at least one value metric, which in the model framework is defined by its CoC. Each asset has at least one single PoF and one LoC/CoC pair for each value metric (the LoC may be zero if the consequence described by the value metric is not applicable to the individual asset). Each CoC may also have up to five severity levels, each with their own probability of occurring and cost of consequence.

The risk cost is the sum of the product of the three parameters for each possible combination of consequence category and severity.

Each of the three major components of the Risk Cost formula are described in detail in the following sections.

3.2.1 Probability of Failure

The first requirement for a risk to be realised is that the asset must fail. The failure is what gives rise to the potential for consequences.

The Probability of Failure (PoF) is the probability that the asset experiences a functional failure that prevents it from providing its primary function during a single year. For most of SA Power Networks' network assets, the primary function is to transmit, or assist another asset to transmit, electricity.[4]

This definition of failure excludes minor or potential failures where the asset continues to provide its required function. For instance, a conditional failure where a pole is tagged for immediate replacement or refurbishment (pole 'plating') due to significant degradation is not considered a functional failure as the pole continues to hold the conductor up (however, the pole would be expected to functionally fail in a short timeframe if it were not replaced).

The most common failure modes for distribution assets are repairable and non-repairable. Where sufficient detail is available, additional failure modes may be considered.

- Repairable: A failure is repairable if the failed asset can be returned to service following the replacement of a component/part of the asset, while retaining other components that were not affected by the failure. Additionally, the repair must be either cheaper or faster to implement than a replacement, otherwise replacement would be strictly preferred. This is generally the case for linear assets (conductor and cable).

- Non-Repairable: A failure is non-repairable if the only action that will restore the functionality of the asset is to replace the failed asset. The model assumes replacement after a failure is like-for-like with a brand-new modern equivalent of the failed asset, with no change in SA Power

[3] This only applies to non-linear assets. Linear asset failures may be repairable.

[4] Some failures may result in the transmission of electricity being unaffected, but the asset is in such a critical state that it must be replaced. As example is a pole breaking but the conductors taking the weight and remaining functional. For clarity, this is considered a functional failure as the primary function of the pole includes holding the conductors a safe height above the ground and taking the stress of the conductor weight.

Networks' network configuration. This is generally the case with non-linear assets (transformers, poles, etc).

In the model each asset failure mode is matched to one or more consequences. Minor repairable failures of some zone substation assets may have only limited consequences (for instance where redundancy exists). Although this may underestimate the total risk, the costs associated with repairable failures of these assets are typically opex (maintenance) costs and the risk outcomes of these types of failures are typically low.

The standard setup of the model is for all linear assets (cables and conductors) to be repairable and all other assets to be non-repairable. This is distinct from an asset being able to be *refurbished* - for instance a pole in poor condition may have steel plates welded at ground level ('plated') to extend its life. It is assumed that this refurbishment is not possible after the asset has functionally failed – for instance a pole cannot be plated once it has functionally failed and is no longer supporting the overhead conductor.

The model considers two main modes through which an asset risk can be caused:

1. **Condition driven failure:** the failure of the asset is caused by its condition. Asset condition degrades over time and may be accelerated by environmental factors, wear and tear and random events, causing the probability of failure to increase over time.
2. **Non-Condition failure:** the failure of the asset is caused by an exogenous factor (for example vegetation, vehicle impacts, etc). This type of failure is independent of the asset condition. If the asset were replaced like-for-like with a new equivalent asset the exogenous factor would still result in the failure of the asset. The only way to prevent this type of failure is to replace the asset with a different asset (such as undergrounding overhead powerlines in areas where trees are prone to falling on lines). The probability of a non-condition failure does not change over time.

The total PoF of an asset unit can be approximated as the sum of the condition failure PoF and the non-condition failure PoF[5].

The following sections describe the approaches used to model the two failure modes listed above.

Condition Driven Failure

The PoF for condition-based failures is calculated for each asset from a PoF function that relates asset condition to PoF. The framework allows any appropriate failure function to be used.

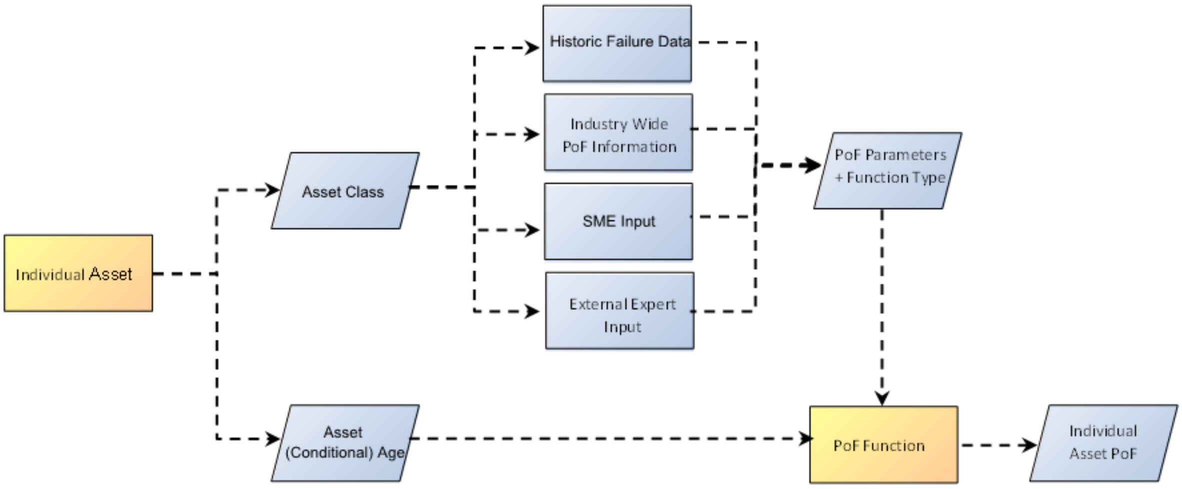
SA Power Networks uses at least two different PoF functions depending on the asset class and data available, the Weibull function and a quadratic function consistent with the Condition Based Risk Management (**CBRM**) methodology. The Weibull function is among the most commonly used PoF functions in the electricity industry, has been endorsed by the AER and is widely used in other industries, particularly where mechanical wear is a major contributor to asset failure. For some asset classes, this function has been further enhanced with the guidance of an external expert engineering consultant. This method makes use of a wider range of asset characteristic data, and machine learning techniques to better differentiate the PoF between assets within the same asset class.

A quadratic function applied to a health score index consistent with the CBRM method (used in SA Power Networks' previous risk models) has been used for some asset classes (such as zone substation assets).

5 The true total is slightly less than the sum due to the probability the asset experienced a non-condition failure before it had the chance to conditionally fail. As the assisted PoF is almost always very low the approximation is very close to the true value.

The parameters of the PoF function are calculated for each asset group. If any sub-groups of assets within a group of assets exhibit a sufficiently different PoF function to the rest of the group, this indicates that the group should be split to enable some of the assets to have a different PoF function.

Figure 3 – Probability of Failure Framework



For all PoF functions used, the PoF is a function of asset age. The parameters of the PoF function are calculated to represent the probability of failure of a typical asset at each year of age.

As not all assets of the same age have the same condition, when the PoF is evaluated for an individual asset unit the actual age of the asset is substituted with an estimate of the unit's conditional age. The conditional age is determined by assessing the condition characteristics of the unit against examples of typical condition characteristics expected for each year of age and selecting a conditional age where these definitions align. For additional detail on the conditional age of assets refer to Section 3.3.

Non-Condition Failure

The PoF for non-condition failures is a fixed percentage value for each asset class and does not change over time. Although this is a simplification, forecasting changes in non-condition failures over time introduces additional uncertainty for an unclear improvement in model accuracy.

The PoF for non-condition failures is calculated from historic data for each asset group as the number of observed non-condition failures divided by the number of assets in service.

Random failures and their associated risks only change with the size of the network (measured as the number of assets), but for modelling purposes only the existing network is modelled. Therefore, the number of non-condition failures will be constant over the modelled period.

For reporting purposes, the value of risk associated with non-condition failures are stored separately to condition caused risks as they are not avoidable.

3.2.2 Likelihood of Consequence

The likelihood of consequence represents a range of information that is used to calculate the probability that a failure leads to a consequence. It is used to model the spectrum of consequences that an asset failure can result in. The likelihood of consequence can vary depending on the nature of the failure, the context and location of the asset, and preventative barriers or controls to mitigate the risk.

LoC is determined for each asset type for each consequence category. That is, for each asset type and each possible consequence, a value is determined for the likelihood of that consequence occurring.

Depending on data availability, the LoC for each risk type is estimated using one of the following three approaches (in order of preference):

1. Historic observed consequence rates after functional failures of SA Power Networks’ assets of a particular asset type
2. Bottom-up estimates where other events are required to occur near-simultaneously for a consequence to be observable. This is appropriate for redundant systems where the probability of multiple failures occurring is the main driver of LoC.
3. Industry Average LoC values used by related businesses/organisations for similar asset types.

The preference is to use historic data to ensure the model reflects real world observations. Using this approach, the LoC is calculated by dividing the number of observed consequences (for each risk type) by the number of observed functional failures for that asset type. This approach requires both asset failures and consequences to have occurred in the past so that an LoC can be determined.

Bottom-up estimates are a reasonable alternative for low probability risks that are unlikely to have been observed historically in sufficient numbers to obtain a reasonable sample size. In these cases, using a LoC with the correct order of magnitude may be sufficient. The probability of other events that need to occur may be known (for instance the failure rates for other assets) and an estimate of the likelihood of a consequence occurring given all other events occur will be sufficient.

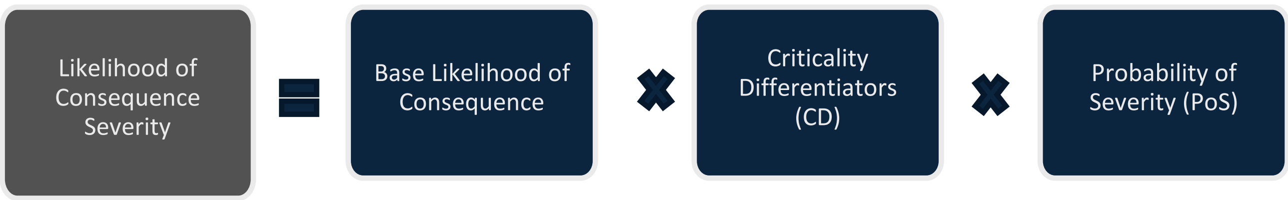
If neither of the other approaches are available, an external source will be used. The LoC in the external source should be compared to the historic data available for SA Power Networks to ensure the estimate is reasonable. For example, if SA Power Networks has had historic failures within the asset type but has not observed any consequences for a particular type of risk, the LoC should be sufficiently low that there would be a reasonable chance of not observing a consequence in the following years.

Sources of industry values used include data from other networks in Australia and from Ofgem (**UK**).

The LoC may be adjusted for individual assets using Criticality Differentiators and may itself be split into severity levels for consequences that have very different risk costs by applying a probability of severity. Both of these are described below.

The formula for a LoC for a specific consequence severity level shown in Figure 4.

Figure 4 – Likelihood of Consequence Severity formula



Criticality Differentiators

The LoC described above is an average value across each asset group. The unique circumstances of an individual asset unit may differ substantially from the average for the group. To address this, Criticality Differentiators (CDs) are applied to either the LoC or CoC.

CDs are applied as necessary on an asset group by asset group basis. Information about the relevant asset attribute used to determine if the CD should be applied must be available as well as data to indicate how much more prevalent consequences are for that characteristic.

Examples of commonly used CDs are:

- Increased LoC for public safety consequences for individual assets located in high population density areas and correspondingly lower LoCs in low population density area.

- Increased LoC for worker safety consequences for individual assets of particular make/manufacturer/technology combinations with known risks or issues that are not present in other assets in the asset group.

The CDs that are applied within each asset group must have a net neutral effect. For every asset that has an above average LoC there must be other assets with a below average LoC such that the overall number of consequences remains unchanged. A calibration module is used for this purpose, with at least one option for each attribute being back-solved to ensure the neutrality requirement is met (for example, the high and medium CDs may be set for an attribute and the low value calculated by the model).

Probability of Severity

The Probability of Severity (**PoS**) is the probability that a consequence that is realised is of a particular severity.

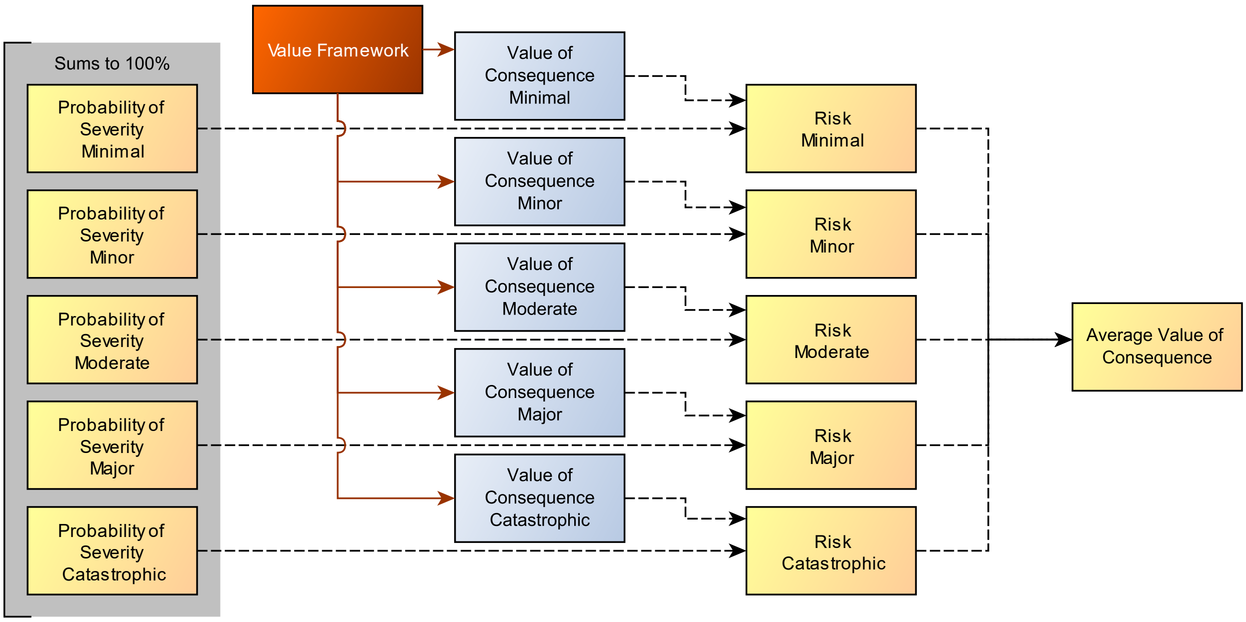
Within the Value Framework, each consequence is determined using either one of two methods:

1. **Value attribution:** applies a specific economic value for the consequence to each individual asset
2. **Value scale:** applies a range of values across defined levels of severity (currently only used for safety and environmental consequences)

PoS only applies to consequence categories that use the value scale approach. In this approach, the PoS values are the weighting factors applied to the values within the value scale. The value attribution approach applies a single value of consequence for each asset, so severity weighting is not required.

The figure below shows how PoS is incorporated into the calculation of the average value of consequence in the value scale approach.

Figure 5: Application of the Value Scale Approach and PoS



The sum of the PoS values must be 100% as each consequence that is realised must correspond to one (and only one) severity level.

From this, the LoC for a specific consequence category and severity level is:

$$LoC_{category,severity} = LoC_{category\ total} \times PoS_{severity}$$

The PoS input parameters are estimated using historic consequence data where available. This is preferably related to consequences of an individual asset type, but where different asset types have similar consequences, averages over a larger number of asset types may be used.

For safety consequences, due to there being very few examples of safety consequences observed by SA Power Networks and the wider industry from which to develop model parameters, estimates developed by Ofgem in the UK have been adapted for use within this framework.

3.2.3 Cost of Consequence

The CoC is taken directly from the Value Framework.

For some consequence categories (such as reliability and bushfire safety) the CoC is calculated individually for each asset (referred to as the value attribution approach in the Value Framework). This calculation may be done inside the model or be already calculated in the model inputs.

Refer to the Value Framework for additional detail.

3.3 Asset Condition and Deterioration

Asset condition and the change in condition over time is the underlying driver of the probability of failure of an asset and is the key determinant of the change in risk over time. This in turn determines when asset replacement and refurbishment investments can be justified.

The PoF of an asset is calculated from a PoF function, which takes asset age as its input for each individual asset, with other parameters determined at an asset group level based on historical data and experience.

Asset age does not represent the true condition of an asset as the condition of assets can deteriorate at different rates due to various factors. The model framework allows for the age of individual assets to be adjusted to reflect the actual condition of the asset. This is referred to as the 'conditional age' of the asset.

The sections below discuss how the model framework addresses:

- Initial asset condition
- Change in condition over time
- Post-investment condition

3.3.1 Initial Asset Condition

The initial asset condition is determined by the individual asset's actual age and any information about the current condition of the asset. This is combined to produce a 'conditional age' for the asset. The conditional age is the age of a similarly degraded asset, which may differ from the actual age of the asset.

The PoF function for each asset group represents the PoF of a typical asset at each given year of age. This can be extended to mean the typical level of deterioration or defects present in an asset of a given age. By analysing the prevalence of defects within certain age bands for an asset group, counts of different types of defects on an individual asset can be used to determine an appropriate conditional age for the asset.

This approach can only be applied to asset groups where a sufficient amount of condition information (such as defects found during inspection) is available. The model can also consider failure rates of nearby assets if there is evidence to support a geographical factor present that is causing accelerated deterioration of assets.

Where no condition information is known for an asset, it will default to using its actual age as the conditional age.

3.3.2 Change in Condition Over Time

The model operates in one-year increments, so that after the results are calculated for a given year the asset base will be updated with replacements and failures and then all individual assets will have their age increased by 1 year.

Subject to data availability, individual assets or assets in certain geographic conditions (ie. soil salinity, coastal corrosion) that have historically shown a faster than average rate of degradation can have their age increased by more than 1 year per year. Alternatively, these assets may be grouped into a separate asset class and have a tailored PoF function that reflects the degradation rate of the asset sub-group. Both approaches require the necessary data to prove the accelerated deterioration is required.

3.3.3 Post-Investment Condition

The condition of an asset may change after an investment is applied. This includes proactive investments to replace (or refurbish) an asset before it fails and reactive investments that occur after a functional failure of the asset. The change in condition is represented in the model as a change in the conditional age of the asset.

The rules used to determine the conditional age after investment are presented in the Table 1.

Table 1 – Post investment condition approach

Investment Type	Post-Investment Condition Approach
Asset Replacement	The conditional (and actual) age of the asset is reset to zero. Normal asset ageing continues for the newly installed asset.
Asset Refurbishment	The conditional (and actual) age of the asset is reduced but not reset to zero. Normal asset ageing continues for the refurbished asset.
Asset Failure – Repairable	The conditional age of the asset remains unchanged after the failure and subsequent repair.
Asset Failure – Non-Repairable	The asset is replaced and the conditional (and actual) age reset to zero. Normal asset ageing continues for the newly installed asset. The post-investment condition is the same as for an Asset Replacement.

3.4 Investment Evaluation

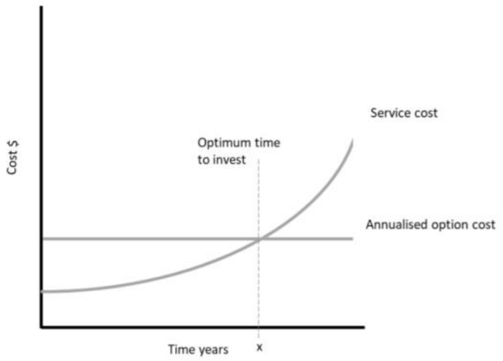
To follow good investment decision making practices, the timing of investments must be optimised. This requires each investment to be evaluated against the same investment made one or more periods later.

In the case of this model framework, which operates at an annual timescale, the optimal timing test is to determine if deferral of one year would be more beneficial than investment in the current year.

When comparing immediate investment versus deferral of one year (replacing at the start of next year), the risk of the replacement asset failing next year is effectively identical for both options (in both cases the asset is either brand new or only one year old) and can therefore be ignored. The only year where there is a significant difference in risk for the replaced asset is the current year, when the deferred option still has the existing (relatively poor condition) asset while the investment option has a new (good/perfect condition) asset. Therefore, only consideration of the first year is necessary to determine whether to invest.

This is the same as the approach proposed by the AER in the *Industry practice application note for asset replacement planning.* The AER shows optimal investment timing in the figure below, where service cost is the avoidable annual cost (inclusive of risk) of the existing asset.

Figure 6: AER Optimal Investment Timing Example



The model framework uses a Benefit-Cost Ratio (**BCR**) approach to evaluate investments. This approach determines whether investments provide positive value and demonstrate capital efficiency. It can also be used to rank competing investments.

The BCR is the ratio of investment benefits (mitigated risk and avoided opex) in the first year after investment to the cost of the investment for that year. The cost of investment has been calculated as the equivalent annual cost using the annuity value based on the WACC and the expected investment life as the annuity period. This can be expressed as the following:

$$BCR = \frac{Benefit_{first\ year}}{Annualised\ Cost} = \frac{Consequence_{existing} \times PoF_{(Cond)existing} - Consequence_{new} \times PoF_{(Cond)new} + (Opex_{existing} - Opex_{new} + Other\ Benefits)}{\left[\frac{Investment \times WACC}{1-(1+WACC)^{-Investment\ Lifetime}}\right]}$$

$$Where: Consequence = \sum_{r=risk\ category\ 1}^{risk\ category\ n} LoC_r \times CoC_r$$

Where an asset is not replaced like-for-like, the average risk for a failure may be different for the existing and new assets. The average risk is itself a function of the LoC and CoC across all risk categories (see Section 3.2 for detail).

The Investment Evaluation module uses the BCR, along with other information and model settings to select projects for investment and optimise the financial and risk budgets over the forecast period.

3.4.1 Benefit

Within this model framework benefits are only calculated for the first year after the investment is made. This aligns with costs, which are also in an annualised form. This design feature simplifies the model and produces similar results as using a full forecast of benefits over all future years in all but extreme cases.

There are two categories of benefits:

1. PoF Driven: Avoided risk
2. Non-PoF Driven: Opex savings

The risk benefit is in annual terms due to the PoF representing the annual failure rate of the asset. The PoF for a new asset ($PoF_{(Cond)new}$) will be very close to zero in most cases (and so may be assumed to be zero in the model) so the benefit is approximately equal to the risk of the existing asset.

Non-PoF driven benefits are most often in the form of opex. The model only considers the incremental differences between the opex of new and existing assets. Where the opex of the new asset is expected to be lower than for the existing asset, the value of the difference (the avoidable opex) will be a benefit. Where opex increases post-investment (such as when contracting non-network options from third-parties), this is included as a negative benefit (only capex costs and non-recurring opex are included in the denominator). If the net of opex increases and savings from repex is material, we may propose an opex step change to account for this.

Other non-PoF benefits may be included, but these are not often easily monetised and therefore are not included in the model.

3.4.2 Cost

The BCR uses annualised investment cost as the denominator, so the BCR will be greater than 1.0 if the benefit during the next year is greater than the cost of the investment over the next year. If this holds, then the lost benefit of waiting another year to invest is greater than the cost of the investment over the same year.

The annualised investment cost is calculated using the following formula:

$$Annualised\ Investment\ Cost = \frac{Investment \times WACC}{1-(1+WACC)^{-Investment\ Lifetime}}$$

The contribution from capex is the cost of financing the capex cost for one year and depreciation of the asset over the first year. The formula uses an amortisation approach where the annualised cost is equal in all years until the end of the investment lifetime. This differs to the approach used by the AER in setting revenue and RAB but is recommended by the AER in the *Industry practice application note for asset replacement planning*. Tax implications are not considered in the formula.

3.5 Investment Plan

The model is able to implement various constraints that influence the investments that will make up the annual investment portfolio. This includes the major constraints, such as budget limits and requirements for investments to be cost-benefit positive, but also includes more nuanced constraints that reflect strategic objectives, managerial discretion and allowances for unmodelled information.

The model is configured to produce results for (at least) the following scenarios:

- Minimise risk at a portfolio level within a total budget.
- Minimise risk within each asset class within asset class specific budgets.
- Maintain risk at a portfolio level at least cost.
- Maintain risk within each asset class at least cost.

The investment plan selects investments from highest BCR to lowest, except where a constraint is enforced. Additional scenarios may be developed through customer engagement.

Multiple Investment Options

An individual asset may have multiple investment options, such as addressing individual defects and replacement. The investment plan only considers a single investment for each asset, which is the investment that has the highest CBA ratio of all possible investments for the asset. This avoids double counting of investments on individual assets.

Investment Planning Over Time

The investment plan is also applied over time. As more investments are made, the pool of available investments changes. The investment evaluation is updated for the revised asset base each year so that a new set of CBA ratios are provided to the Investment Plan module for determining the investments in the new forecast year.

Budget Constraints

Budget constraints may be introduced to limit expenditure forecast in specific years – for instance to account for realistic ‘ramping up’ of resources that would be required to deliver significant additional investment. Where a budget constraint is applied within a scenario, it must be determined if the constraint should apply to proactive repex only or to total repex.

Where the constraint applies to total repex, the selection of proactive projects must stop at the point where the expected cost (including the reactive replacement cost premium) of failures of assets not replaced equals the remaining budget.

The expected cost of reactive replacements is the sum of $PoF_{condition}$ x (Replacement Cost + Reactive Replacement Premium) across all assets not replaced proactively.

For non-condition failures, the expected cost of these should be removed from the budget before any selection of proactive replacement investments. This is equal to $PoF_{assisted}$ x (Replacement Cost + Reactive Replacement Premium) for all assets, including those that may be replaced.

3.6 Forecasting Over Multiple Time Periods

This section covers the processes for moving the model simulation forward through time.

This includes:

1. Rolling forward the asset base.
2. Calculating risk exposure and other information for reporting purposes.
3. Updating other data inputs and looping the model to restart for the next time period.

3.6.1 Asset Roll-Forward

The model iterates year on year. As this occurs, the asset base changes due to the following factors:

1. Asset is changed by a modelled investment.
2. Asset fails due to condition and is replaced reactively.
3. Asset fails due to non-condition based reasons (non-condition failure).
4. Asset is changed due to other (unmodelled) reasons.

The model deals primarily with modelled investment and also considers reactive replacement (both condition and assisted). The model does not (currently) consider unmodelled replacements, which may include network augmentation projects, asset retirements and major projects. Where unmodelled changes to assets are planned/expected, SA POWER NETWORKS will remove the affected assets from the asset base input into the model.

The model will update the asset condition for any asset that is changed. The asset condition is a direct input into the PoF function for that asset and will result in the model calculating a lower PoF.

When the model calculates risk for assets in the following year, the updated asset condition, along with any ageing/deterioration effect, will be used to calculate the new PoF and the resultant asset risk.

Each year, modelled investments and failures occur in the following priority order:

- Proactive replacements – these are assumed to occur at the start of the year. The assets selected for proactive replacement are determined in the Investment Plan module (see Section 3.5)
- Condition failures – these are assumed to occur after replacements are made so that if an asset is identified for replacement the replacement occurs before the asset can fail. Condition failures are applied to the assets within an asset class that have the highest PoF until the expected number of condition failures is reached (equal to the sum of PoF across all individual assets that are not replaced).
- Non-condition failures – these are assumed to occur after all other asset replacements. Non-condition failures are assigned at random to individual assets. For simplicity, an asset that is proactively replaced or has a conditional failure in a given simulated year will be excluded from having a non-condition failure during that year.

Some asset classes may be operated run-to-failure because the assets have a low risk or cannot be reliably identified before failure. In asset classes where proactive investment does occur, not all assets may be caught before they fail.

The expected number of asset failures within an asset class is equal to the sum of the PoF across all assets in that asset class. This calculation uses the PoF after the investments are applied, so that failures can be avoided by investing to achieve a lower risk outcome for the year.

Selection of Assets for Condition Failure

The following approaches are used to select which individual assets fail.

Asset Classes with >1 Expected Failures

For asset classes with high volumes of units and relatively high PoF values (for instance underground cables), the expected number of failures will be greater than 1 per annum. That allows assets to be treated as failed during the year. The standard approach used in the model is to treat the N highest PoF assets within an asset class as having failed during the year, where N is the sum of PoF for the asset class rounded to the nearest integer value. The actual and conditional age for these units is updated to zero years.

Asset Classes with <1 Expected Failures

The model will not apply failures to asset classes with less than 1 expected failures per annum. Asset classes where this occurs are usually significant assets, such as zone substation transformers, which fail rarely and may have high consequences when they do fail. For risk calculations, a fraction of an asset failure (and the associated risk) will be recorded and added to the model results, but this will not result in a change to the asset base.

Repairable Asset Classes

Repairable asset classes are not changed after failure. Therefore, individual assets are not identified as failed in the model and replaced.

3.6.2 Risk Calculations

Calculate Risk Incurred

Risk incurred is the sum of the risk consequence per failure event (LoC x CoC) for the assets deemed to have failed.

For repairable asset classes the individual assets that fail are not identified. The risk incurred is calculated across all assets in the asset class and is equal to the carrying/inherent risk (PoF x LoC x CoC).

Calculate Carrying / Inherent Risk

The carrying or inherent risk of the asset base is the expected value of risk associated with all installed assets. For a given year, this risk is calculated using the assets that are in place after investments are applied but before asset failures are applied.

In most cases the carrying/inherent risk will be approximately equal to the risk incurred. However, risk incurred is more volatile year-to-year as it depends on which assets are selected to have failed and the average risk cost per failure for those assets. Carrying/inherent risk is probabilistic and therefore is smoother over time.

3.6.3 Next Period Loop

Data used by the model must be updated before calculations can be re-run for the following year in the simulation.

The risk calculation needs to be updated for any asset that changed during the current year. The available investments will also change (i.e. if an asset is replaced it no longer has defects that can be refurbished).

Any asset that has changed (either due to investment or because it has failed and is non-repairable) is updated with new PoF, investment options and other parameters as required.

All assets that have not otherwise changed have their conditional age and actual age increased by one year.

CoC inputs are escalated as required. As the model operates in real terms, only changes in real value are required to be applied. Escalation requirements are detailed in the Value Framework.

For scenarios where there are budget or risk limits imposed, these may change over time and therefore need to be set to the appropriate value each year.