Model Framework

February 2022

Version Control

Revision	Date	Description	Author	Endorsed	Approved
1.0	30/09/21	Draft Model Framework	R. Kerin	R. Dudley	R. Dudley
2.0	15/02/22	Updated Model Framework	R. Kerin	R. Dudley	R. Dudley
3.0	06/07/22	Amended to be a description of how the model functions	M Van Doonrik		

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Glossary

Term	Description
PoF	Probability of Failure – the probability an asset will functionally fail during a single year
LoC	Likelihood of Consequence – the probability that a consequence occurs (given an asset has already failed)
CoC	Cost of Consequence – the (monetised) cost that will be incurred by Power and Water/customers/society if a consequence occurs
PoS	Probability of Severity – the probability a consequence is of a particular severity (i.e. minor injury vs major injury)
Conditional failure	An asset fails a serviceability criteria but remains functional
Functional failure	An asset fails to provide its primary function (i.e. a pole breaks and no longer holds conductors safely above the ground)
Repairable	An asset can be repaired
Non-Repairable	An asset cannot be repaired and must be replaced
Condition driven failure	An asset failure caused by deterioration in asset condition over time
Assisted failure	An asset failure caused by an exogenous event (such as impact by a motor vehicle) unrelated to asset condition (brand new asset would also have failed)
Weibull function	A statistical function commonly used for describing mechanical deterioration of physical assets over time
Criticality differentiator	A factor that differentiates an individual asset unit from a typical asset of the same type
BCR	Benefit Cost Ratio – the ratio of benefits to costs, calculated as total benefits divided by total costs

1 Introduction

This document sets out details of Power Services volumetric model. This document provides a description of how the Risk Quantification Procedure[1] has been applied for forecasting replacement capital expenditure of volumetric assets to support Power and Water's financial forecasts and for use in regulatory submissions.

Risk is assessed and evaluated to enable the selection of the optimal set of investments to support both long term asset replacement planning as well as short term asset performance. This is achieved by calculating risk in monetary terms and optimising the set of investments applied to the asset base to maximise net economic benefits and to assess real world scenarios.

This model has been developed based on the Risk Quantification Procedure, which applied the principles set out by the Australian Energy Regulator (AER) in the *Industry practice application note for asset replacement planning*[2] (the ARP note).

Power and Water has developed an Enterprise Risk Management Standard to ensure that regular assessments are undertaken to identify and manage significant risks to the community as a result of its activities. These risks include health and safety, hazards and security, service delivery, financial, legal and regulatory, environmental and reputational risks. The risks are managed throughout the organisation in line with the Audit and Risk Management Committee's charter and risk management process.

This model has been developed in alignment with the Enterprise Risk Management Standard and provides a framework for the quantitative assessment of risk within Power and Water's total capital expenditure forecasts.

1.1 Purpose

This document describes how the Risk Quantification Procedure has been applied to enable the selection of the optimal set of investments in support of both long-term asset risk decision making as well as short term asset performance.

It is intended to define the calculations undertaken in the model, how the Risk Quantification Procedure has been applied and how the model works.

1.2 Scope

This document describes the replacement capex forecasting model for volumetric programmes. The model framework has been implemented in an Excel spreadsheet.

1.3 Structure

- **Section 2** describes how the model functions from an application point of view. The theory and calculation approaches are available in the RPQ. The description is based on the Base Case Model
- **Section 3** provides a flow diagram for each of the model versions created. They all work predominately the same, with the difference being in the logic applied to select which assets to replace or not
- **Section 4** provides a list of the assumptions and their justification and data sources.
- **Section 5** describes the calculation of BCR which is a key decision-making factor within the model.

[1] CONTROL0932, Power and Water Corporation Risk Quantification Procedure
[2] https://www.aer.gov.au/system/files/D19-2978%20-%20AER%20-Industry%20practice%20application%20note%20Asset%20replacement%20planning%20-%2025%20January%202019.pdf

2 Application of the model in Excel

The model overview in Figure 1 below describes the high-level concept of the model. It provides an overview of how the model functions and the key types of inputs that are used to drive the model results. The yellow boxes indicate major modules while the blue-grey slanted boxes indicate data inputs and outputs.

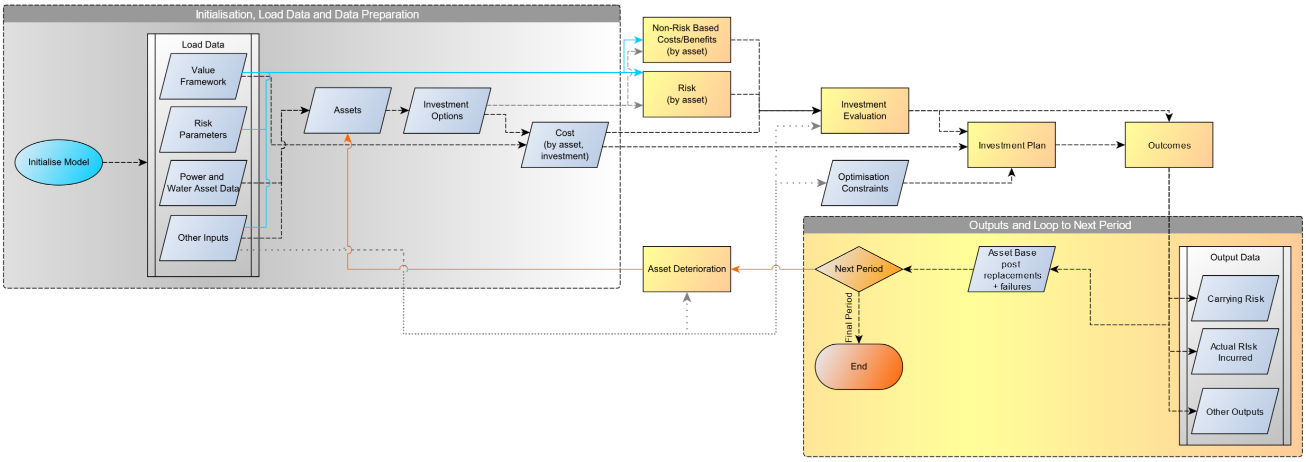

Figure 1: Model overview diagram

Figure 2 shows the high-level view of how the information flows between tabs in the model and the different calculations performed. The legend at the top of the flow diagram indicates what is being done in each of the broad steps.

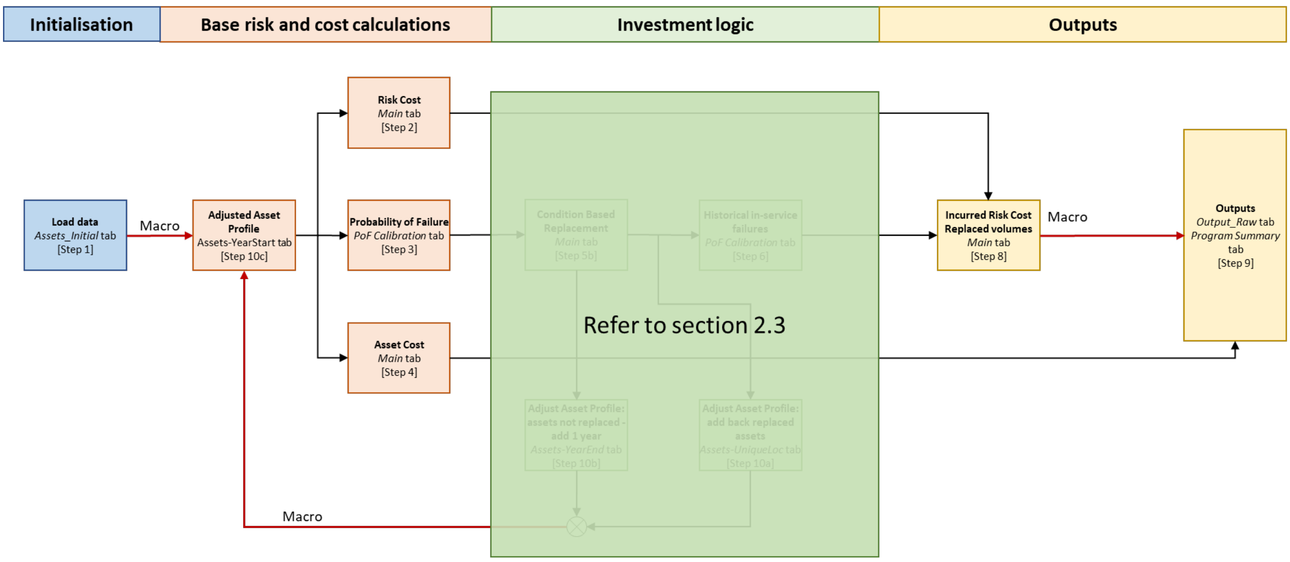

Figure 2 Generic model logic and information flow diagram

The four key components of the model are:

- ***Initialisation –*** this section describes how and why the asset data has been configured into the format used in the model
- ***Base risk and cost calculations–*** this section describes how the model calculates the probabilities, consequences, and asset costs that are used throughout the model. This includes how assets deterioration is modelled.

- ***Investment logic* –** this section describes how the model evaluates and ranks all possible asset investments and selects investments that will be undertaken based on the scenario being assessed

- ***Outcomes* –** this section describes how the outcomes of the other modules are recorded by the model and used to inform risk and investment in following years of the simulation

This description of the model focuses on the functionality and core components. We note that there are a number of additional tabs that provide inputs to the model. These tabs are not described in detail, but the assumptions applied are described below and in section 3.

2.1 Initialisation

The asset profile was calculated in a separate spreadsheet[3] in order to manage the size of the file and calculations required to be undertaken in each iteration of the model. This model was only required to be run once and the outputs were entered into the '*Assets_Initial*' tab

The asset profile groups assets with similar asset type and risk characteristics. To do this, each of the asset classes were grouped and allocated to a single line item in the asset profile table. The attributes that were used to define similar asset classes are shown in Table 1 and described below.

Table 1 Attributes used to define unique asset groups

Customers	Region	Feeder	Type	[spare x 17]	Asset Class ID	Age	# Units

- **Customers:** the number of customers downstream of the asset that would be impacted by its failure. This enables assessment of the cost of an outage.

- **Region:** Identifies if the asset is located in Darwin, Katherine, Tennent Creek or Alice Springs.

- **Feeder:** the feeder category of Rural Long, Rural Short, Urban and CBD.

- **Type:** used to define the insulation medium for a circuit breaker or distribution switch. This related predominantly to the safety and environmental consequence.

- **[spare x 17]:** these are 17 spare categories (columns set to 0) that can be used to include additional unique identifiers should we need to provide further granularity in the asset groupings.

- **Asset Class ID:** this is the asset category the asset is assigned to in the CA RIN. Each asset class was assigned a unique Asset Class ID (a number from 1 to 67).

- **Age:** the age of the group of assets

- **Units:** the number of assets. Units for discrete assets and metres for conductor and cables.

The outcome was a unique identifier per similar asset group in the form of '10-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-31' which created 12,641 unique asset groupings. The purpose was to model assets with similar risk characteristics as a group, rather than individually, and therefore reduce the size of the data set.

[3] File name: PWC RvE Model – Asset Inputs v0.7.xlsx

2.2 Base risk and cost calculations

The calculation of risk has been implemented as set out in the Risk Quantification Procedure. The following section describe the sources used and/or assumptions made (including justification) to determine the values of the parameters used. Additional general assumptions are provided in section 4.

2.2.1 Probability of Failure

The model considers condition based failure as the main mode through which an asset risk can be caused. 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.

The PoF for condition-based failures is calculated for each asset from a PoF function that relates asset condition to PoF. The model uses the industry standard Weibull function, a probability distribution defined by three parameters and uses the age of the asset as a proxy for its condition to estimate the PoF of each asset.

The parameters of the Weibull 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 is split to enable some of the assets to have a different PoF function.

Figure 3 shows the information used to develop the asset specific probability distributions. Where sufficient historical information is known about the asset class, particularly the age of assets at failure, the actual data was used to calculate a probability function.

Where insufficient data was available, the model is initialised with the expected asset ages from the mean economic life in the Category Analysis RIN Table 5.2.1 and the shape factor was set to 2, as it approximates a normal distribution. The exception was for poles, pole tops and LV switchgear where the shape factor was set to 4.5 as these assets have been identified by other NSPs as having higher shape parameters. The 4.5 value was used to align with guidance from the AER[4].

The asset age was then adjusted to calibrate the first year of forecast replacements to equal the average of the previous five of years of historical replacements. The probability distributions are calibrated once prior to running the model.

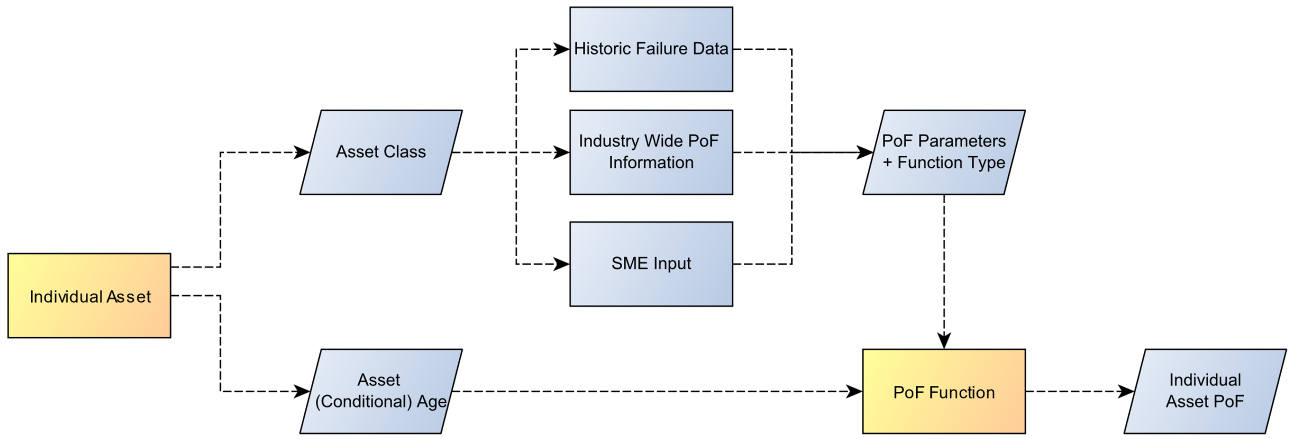

Figure 3 Information flow for calculation of PoF

[4] AER - Asset replacement forum -Discussion summary - 26 February 2019.pdf. The AER stated that Weibull shape factors greater than 5 are generally not considered plausible. Hence, where sufficient data is not available to calculate a shape factor, Power Services has taken the AER's concerns into account and limits the maximum shape factor to 4.5.

We note that the model incorporates the functionality for assisted failure. An assisted failure occurs when the failure of the asset is caused by an exogenous factor. 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 the network in areas where trees are prone to falling on lines). Typically, the probability of an assisted failure does not change over time. However, without sufficient data to support this input we left it as zero to exclude it from the forecast.

2.2.2 Risk cost

The risk cost is calculated based on the product of the four components. The risk incurred is then the probability of failure multiplied by the total possible risk cost. The four inputs are:

- Likelihood of Consequence
- Criticality Differentiators
- Probability of Severity
- Cost of Consequence.

The methods used and assumptions made to derive the appropriate values for the inputs are described below.

2.2.2.1 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 was estimated using one of the following three approaches (in order of preference):

1. **Historic** observed consequence rates after functional failures of Power and Water's assets of a particular asset type. This was the preferred method. Using this approach, the LoC was 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 required both asset failures and consequences to have occurred (and have been accurately recorded) in the past so that an LoC can be determined.
2. **Bottom-up** estimates where other events are required to occur near-simultaneously for a consequence to be observable. This approach is based on SME engineering input to develop an estimate of the probability of each consequence occurring where none have previously occurred on the network, or have not been observed historically in sufficient numbers to obtain a reasonable sample size.
3. **Industry Average** LoC values used by related businesses/organisations for similar asset types. 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 Power and Water to ensure the estimate is reasonable. For example, if Power and Water 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.

Specific assumptions made for each of the LoC areas are listed below:

- For network performance we assumed an asset failure would always result in an outage for LV and HV (set to 100%) but only part of the time for subtransmission due to the potential for redundancy (set to 20%).

- The Ofgem values, as set out in the Risk Quantification Procedure, were used to derive a LoC based on the sum of the probability of death or serious injury and the probability of a lost time accident.
- Environmental consequence was only applied to transformers and switchgear which contain oil or SF6 gas. The quantity of oil/SF6 contained in assets is based on data from other networks and allocated at a RIN asset category level. This assumes all assets within the same category contain the same quantity of hazardous material. The LoC was calculated as the average number of consequences observed 2014-2021 for each asset group divided by the number of expected asset failures in the first year of the model.
- The LoC of fire was calculated by dividing the average number of fires reported per annum over the past 20 years by the number of asset failures in the first year of the model. Due to limited data, the LoC for fire has been set to the same value for all assets. Overall fire risk is very low so the impact of inaccuracy for this risk category is not considered material.

2.2.2.2 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.

It is necessary that information about the relevant asset attribute used to determine if the CD should be applied is known as well as data to indicate how much more prevalent consequences are for that characteristic.

CDs were only applied for safety consequences. Service delivery was already based on historical data so it is sufficiently adjusted for the impact based on the number of down stream assets. We did not consider that CDs were appropriate to be applied to the other categories as they are largely independent of the proximity of the public.

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.

We calculated the CDs based on customer density as a proxy for the proximity of the public to an asset. The customer density (customers per km) of the HV feeders was calculated as the sum of customers divided by the sum of overhead and underground HV line length, for each feeder category: CBD, urban, short rural and long rural. The customer density was then multiplied by the proportion of assets located on that feeder type (calculated as a percentage of all assets). This calculated a factor to differentiate between the risk posed to safety as a function of the number of assets and proximity of people.

This data was then normalised so that the average value across all assets would be 1. We applied the normalisation on an asset basis rather than feeder basis, then aggregated back to a feeder level for implementation. The reason for this approach was that since the number of assets per feeder differs, the overall probability of safety consequences differs. Where the feeder category was not available, it was allocated a value of one so it remained neutral. Since the risk is calculated on a per asset basis, this approach enabled us to keep the overall impact of the CDs neutral.

This method was applied as the risk of a safety impact is increased where the asset is in closer proximity to the public. Hence this is a reasonable method for adjusting the risk cost of an event.

2.2.2.3 Probability of Severity

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

The values applied in the model are the same as those set out in the Risk Quantification Procedure.

We note the following specific assumptions:

- The data obtained from Ofgem only has two severity levels rather than the five used by Power and Water. Hence, we applied a method to convert the Ofgem data into the five levels required by our procedure, while conserving the total probability of a safety incident occurring.
    - The Ofgem death and serious injury category was used to create our major and severe levels
    - The Ofgem loss time injury was used to create the insignificant, minor and moderate levels
    - Our methodology applied two arbitrary factors as part of the allocation that create the differentiation between the five levels. We undertook an visual assessment to check for reasonableness of the trend and also undertook sensitivity analysis of the output risk and cost from the model and found that changing the values within a reasonable range did not create a material change in the output.
- Due to a lack of available data, a simple declining probability curve was used for the other categories. The bulk of the probability (70% and 20%) is allocated to the bottom two severity levels and only 0.1% to the highest level. These values were selected to produce reasonable weighted average consequence costs based on values estimated by peer networks. We note, that the majority of the risk is derived from safety and the service delivery categories which are calculated based on industry data and historical outage data, respectively, so the impact is not considered to be material.

2.2.2.4 Cost of Consequence

The Cost of Consequence (CoC) is applied directly from the Risk Quantification Procedure.

2.2.3 Asset cost

There are two types of failures in the model, repairable and non-repairable. In the model each asset class is assigned to one of the two repairability types:

- **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.

- **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 Power and Water's network configuration.

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. The model includes the cost of the repair as a (financial) risk even if it is not recorded as repex.

The costs applied in the model are calculated from historical expenditure reported in the RINs, adjusted to FY22 dollars and with the labour rate adjusted to the appropriate level currently in use.

2.2.4 Asset age adjustment

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 model is automated by a macro that enables it to loop through the calculation a number of times, as specified by the user. In each iteration, the model calculates the number of replacements (economic or condition based), ages the asset base that is not replaced by one year, then adds in the assets that were replaced with an age of 1 year.

The rules used to determine the conditional age after investment are presented in the table below:

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 Failure – Repairable	The conditional age of the asset remains unchanged after the failure and subsequent repair.
Asset not replaced	The asset age is incremented by one year and the model is re-run.

3 Investment logic

Four versions of the model have been established to assess four different scenarios. Due to the size of the model and run time to complete a forecast, it was necessary to create separate versions rather than implement the logic for different scenarios into a single model.

The four scenarios we have assessed aim to cover the set of credible options that are available for managing this asset fleet. These are:

- Option 1 – reactive replacement only (counterfactual case)
- Option 2 – Condition based and reactive replacement
- Option 3 – Proactive (economic) replacement plus reactive replacement
- Option 4 – Maintain risk

The logic applied to model each of these scenarios is described in the following sections.

We note that an individual asset may have multiple investment options, such as addressing individual defects and replacement. However, for simplicity, the model only considers repair (for linear assets) or replacement with an equivalent asset. We consider that this is an immaterial impact to the forecast as any assets with specific type issues or circumstances that would give rise to alternative options have been separated out into separate programs and are not included in this model. This approach is consistent across all four scenarios.

3.1 Option 1 – Reactive replacement only (counterfactual case)

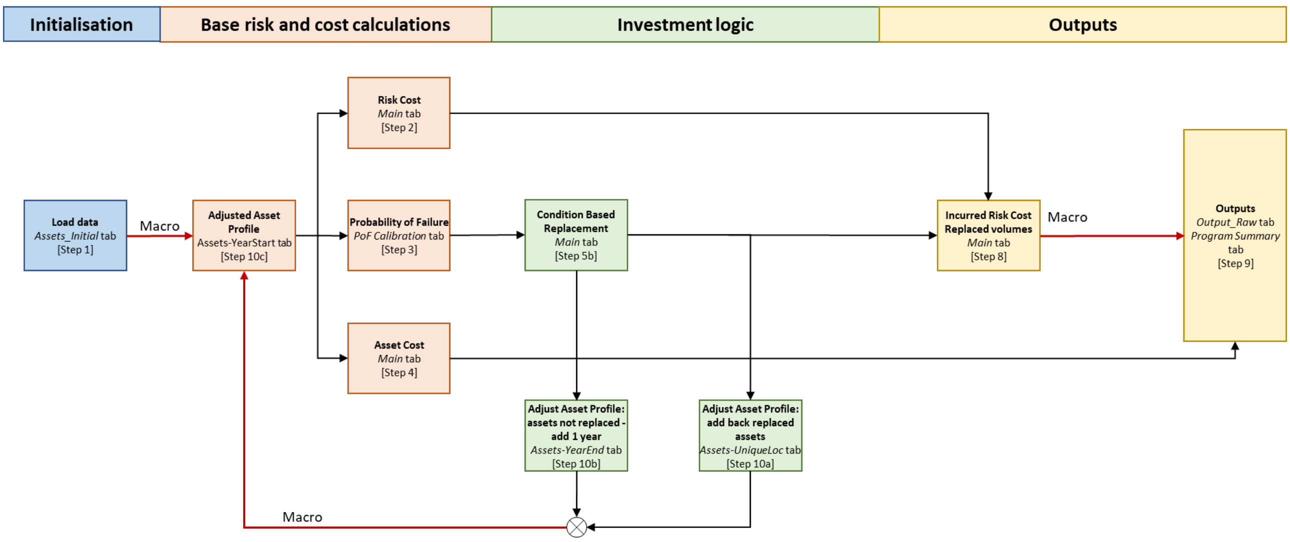

Figure 4 Application of model in Excel showing the logic and information flow for Option 1

The logic of Option 1 is relatively simple. It assumes that there is no proactive replacement, neither on a economic or condition basis, so all assets that reach end of life will fail. Since all replacement is assumed to occur following failure, the full risk is incurred and all asset replacements or repairs incur the reactive replacement premium.

This is shown in Step 5b in Figure 4. All assets that fail are assumed to be replaced as, maintaining supply is a licence and NT NER obligation, and are added back to the age profile with an age initialised to one in Step 10a. Step 10b extracts the assets that are not replaced and increments them by one year. Step 10c combines the data sets from Steps 10a and 10b and inserts them into the '*Asset-YearStart'* tab so the model is ready to iterate again with the updated age profile.

3.2 Option 2 – Condition based and reactive replacement

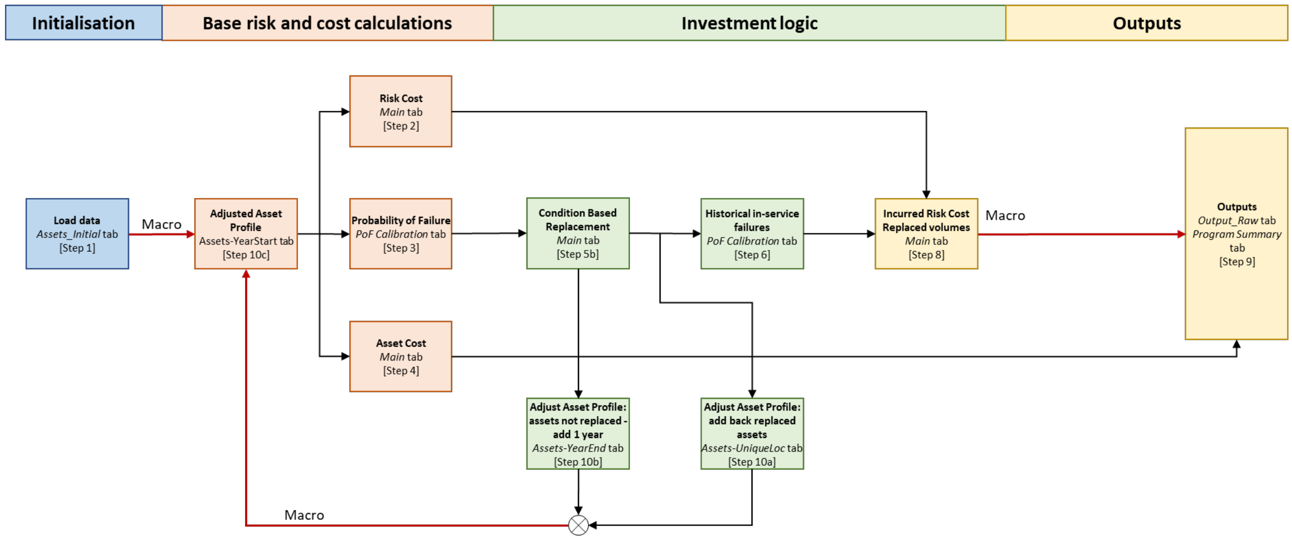

Figure 5 Application of model in Excel showing the logic and information flow for Option 2

The logic of Option 2 expands on Option 1 by including an allowance for assets that are replaced based on condition prior to failure.

Historical in-service failure data is used to identify the proportion of all assets that were replaced during the past five years that were replaced following failure. This provides a realistic assessment of the ability of field crews to identify assets in poor condition and take action before they fail.

The method to calculate the number of assets that reach end of life is the same as Option 1 but then Option 2 applies and additional calculations:

- The number of assets that reach end of life are multiplied by the historical average percentage of assets that have failed in service. This proportion of the assets incurred the reactive replacement premium to their unit cost and the apportioned value of risk was also incurred.

- The remaining assets were assumed to have been discovered by field crew to be in poor condition and replaced prior to failure in a planned manner, hence only incurring the proactive replacement cost (no reactive premium) and not incurring the risk cost.

This is shown in Step 5b and Step 6 in Figure 5. All assets that fail are assumed to be replaced, as maintaining supply is a licence and NT NER obligation, and are added back to the age profile with an age initialised to one in Step 10a. Step 10b extracts the assets that are not replaced and increments them by one year. Step 10c combines the data sets from Steps 10a and 10b and inserts them into the '*Asset-YearStart'* tab so the model is ready to iterate again with the updated age profile.

3.3 Option 3 – Proactive (economic) replacement plus reactive replacement

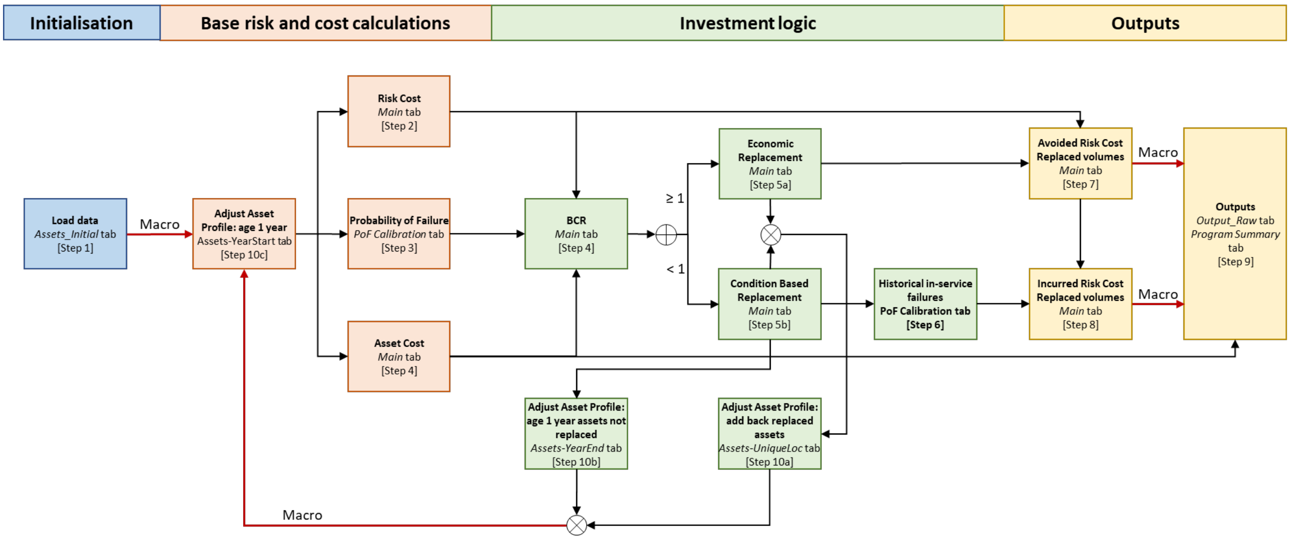

Figure 6 Application of model in Excel showing the logic and information flow for Option 3

The logic of Option 3 expands on Option 2 by including an allowance for assets to be replaced on an economic basis through the calculation of the BCR (refer to section 4). It also allows for assets to be replaced based on condition prior to failure. These steps are described below:

- The BCR is calculated for all assets. Any asset where the BCR is greater than 1 is deemed prudent and efficient to replace. All assets in the line item with the same characteristics are replaced (whereas for condition or failure, the asset replacement volume is based on the expected proportion only). The model applies this rule to the asset profile first.

- The remaining assets are then assessed for condition and failure based replacements:

    - As in Option 2, historical in-service failure data is used to identify the proportion of all assets that were replaced during the past five years that were replaced following failure. This provides a realistic assessment of the ability of field crews to identify assets in poor condition and take action before they fail.

    - The number of assets that reach end of life are multiplied by the historical average percentage of assets that have failed in service. This proportion of the assets incurred the reactive replacement premium to their unit cost and the apportioned value of risk was also incurred.

    - The remaining assets were assumed to have been discovered by field crew to be in poor condition and replaced prior to failure in a planned manner, hence only incurring the proactive replacement cost (no reactive premium) and not incurring the risk cost.

This is shown in Step 4 through to Step 6 in Figure 6. All assets that are assess to be replaced based on economic benefits, condition or failure are added back to the age profile with an age initialised to one in Step 10a. Step 10b extracts the assets that are not replaced and increments them by one year, and Step 10c combines the data sets from Steps 10a and 10b and inserts them into the '*Asset-YearStart'* tab so the model is ready to iterate again with the updated age profile.

3.4 Option 4 – Maintain risk

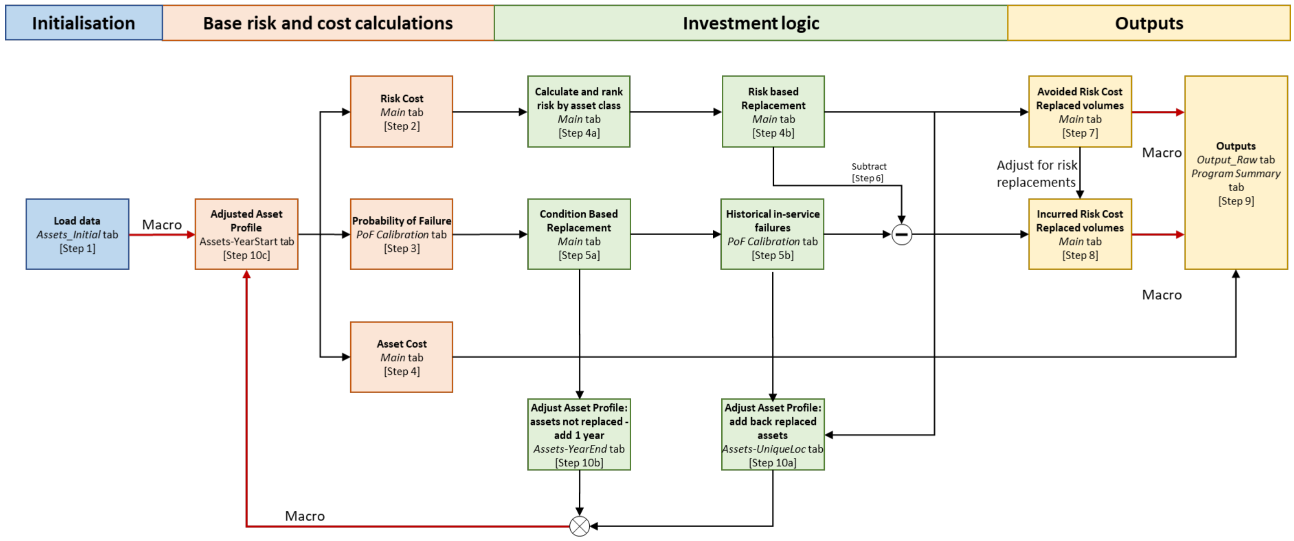

Figure 7 Application of model in Excel showing the logic and information flow for Option 4

The logic of Option 4 is similar to Option 3, however the replacement criteria is based on the cumulative risk of the assets. This calculation is more complex with two parallel processes.

Process 1:

- The number of assets expected to reach the end of their serviceable life is calculated. These assets are assumed to fail.
- The cost of the replacement was adjusted for the reactive risk premium based on the historical in-service failure data.

Process 2:

- Risk is calculated for each of the asset line items, and then ranked within its asset class from highest to lowest. The cumulative risk is then calculated by asset class.
- The total risk cost expected to be present at the start of the next regulatory period was calculated and disaggregated to a RIN category asset level. This set the 'Risk Threshold' for each asset class.
- All assets in each asset category with a cumulative risk level that exceeded the threshold were identified for replacement. In this way, the total risk would remain constant on the network. The total risk of these assets was removed from the risk calculation (avoided risk).

Combining the processes:

- For assets that are not replaced based on risk:
  - the risk incurred is reduced by any avoided risk (refer to Process 2) and the remainder is allocated as planned (condition based) replacement where no risk is incurred or reactive (post failure) replacement where the risk is incurred. The allocation is based on historical data.
  - the cost of the asset replacement for reactive (post failure) replacements incurs the reactive replacement premium.
- Where assets are replaced based on risk:
  - it is assumed to be a proactive replacement (prior to failure) so all the risk is avoided.
  - the reactive replacement premium is avoided for all assets.

This method is shown in Step 4 to Step 6 in Figure 7. All assets that are are added back to the age profile with an age initialised to one in Step 10a. Step 10b extracts the assets that are not replaced and increments them by one year. Step 10c combines the data sets from Steps 10a and 10b and inserts them into the '*Asset-YearStart'* tab so the model is ready to iterate again with the updated age profile.

3.5 Option 5 – Condition based and reactive replacement with capital constraint

Option 5 – Condition based replacement with capital constraint

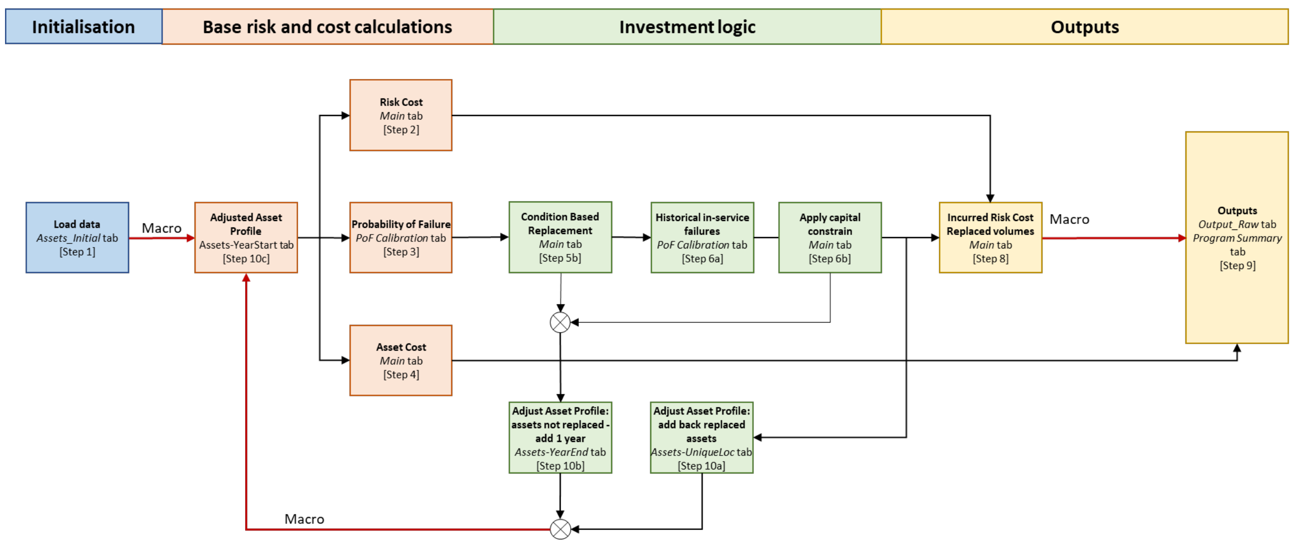

Figure 8 Application of model in Excel showing the logic and information flow for Option 2

The logic of Option 5 expands on Option 2 by including a capital expenditure constraint that limits the expenditure to a pre-determined amount.

The method to calculate the number of assets that reach end of life is the same as Option 2 but then Option 5 applies and additional calculations:

- Where assets are identified as reaching end of life, but are not able to be replaced due to the capital constraint (step 6b), the risk is added to the risk profile (representing the increased risk of a defect on the network) but the asset is retained in the age profile as it is not replaced (Step 10a).
- The total cost of assets considered to have failed is summed and compared to that year's capital limit. If the limit is not exceeded, the remainder of the available budget is used for condition-based replacement (Steps 6a and 6b).
- The condition-based replacement is assessed based on prioritising the assets with the highest probability of failure as a proxy for being in the worst visible condition. The replacements are included while the cumulative capital expenditure is less than the remaining budget.

All assets that fail are assumed to be replaced, as maintaining supply is a licence and NT NER obligation, and are added back to the age profile with an age initialised to one in Step 10a. Step 10b extracts the assets that are not replaced and increments them by one year. Step 10c combines the data sets from Steps 10a and 10b and inserts them into the '*Asset-YearStart'* tab so the model is ready to iterate again with the updated age profile.

3.6 Outcomes

The results of each iteration are calculated in the *Main* tab. The macro copies these results and pastes them as text in the *Output_Raw* tab. They are inserted as text and there are tables set up to summarise the extensive data outputs into useable tabulated data.

The Program Summary tab, then collates the data into the highest level view for use in the business case and cost benefit model.

4 General assumptions

The following sections provides a list of general assumptions, by topic area, as applied in the model.

4.1 Probability of failure

- All assets within a RIN asset category are subject to the same probability of failure function.
- Asset failures follow the Weibull probability distribution with age based degradation.
- The shift parameter is set to zero as there is insufficient failure data to reliably determine a different value should be used.
- The scale parameter is back-solved so that the number of asset failures in the first year of the model is equal to the expected number of failures.
- The expected number of asset failures is calculated for each RIN asset category using failure and replacement data reported in the RIN, averaged over the five years 2015-16 through 2019-20. The data applied excluded replacements related to assets that are being addressed by major projects, which are also excluded from the volumetric forecast.
- RIN asset categories with no asset failure data over the historical period were provided a sufficiently high scale parameter value for expected failures to be very low (<1 p.a.)

4.2 Unit rates

- All assets within a RIN asset category have the same unit rate
- Unit rates were calculated based on a four year period of data used to report expenditure in the Category Analysis RIN. The data was adjusted to only include expenditure that had associated asset quantities and to make adjustments for some outliers or asset types that had not been replaced during the assessment period.
- For pole tops (not in RIN) and some transformer asset categories, we used recent replacement project data. Due to data recording practices used in the field, only projects with a cost above $1,000 were included for transformers.
- All cables and conductors are repaired on failure rather than replaced. Repair are estimated to cost the equivalent of 7m of the asset. This amount was derived from RIN and Power and Water replacement data to ensure the expected cost of repairs in the first year is approximately equal to typical reported expenditure in recent years.

4.3 Outage duration

- outage duration was calculated by voltage level form RIN data (sustained outages table) as the average for all outages where the reason for interruption is “Asset Failure” using 2020 data
- More detailed data was reviewed for the calculation of outage duration (including outages by asset class, feeder type and region), but due to relatively small sample sizes in many of the detailed groups and uncertainty about the categorisation of some outages, it was determined the data produced from this analysis was not of sufficient quality to use in the model.

4.4 Outage – Customers affected

- Services: only affect one customer
- LV network assets: an average of 20 customers are impacted by an outage. This value was based on a an assessment of the average number of customers supplied by distribution transformers across Power Water’s network.
- Distribution transformers: customers numbers impacted were based on the count of attached NMIs
- Switches: customers numbers impacted was based on data for the count of attached NMIs where available. Where data not available, it was set to zero to be conservative.

- HV assets (excl. switches): calculated per feeder, assumes all customers on the feeder experience the outage. A review of the RIN data for number of affected customers for HV outages indicated that in most cases this assumption is appropriate. Supporting analysis for this is available[5].
- Average load per customer:
    - This was calculated as the annual energy delivered as reported in the Economic Benchmarking RIN Table 3.4.1, divided by the total customer count as reported in Annual RIN Table 6.2.4, divided by the number of hours per year (8,760). This resulted in an average per customer of 2.2 kW.
    - All customers are assumed to have the same average load
    - The timing of outages (peak vs minimum demand) is not considered. It is assumed that on average, outages will occur randomly across the day, then the impact is that the average demand applied for all outages is appropriate.

4.5 Financial

- Discount rate is Power and Water's WACC (real vanilla) reported in 2021 PTRM.
- VCR applied was from the most recent annual update from the AER[6]

[5] Outage analysis mode "*hv sustained interruptions affect cust.xlsx*"
[6] AER, Values of customer reliability – Annual adjustment summary, December 2021

5 Investment timing calculation

We have calculated the optimal time for replacement on an economic basis using the Benefit Cost Ratio (BCR). This approach is consistent with the AERs replacement planning guideline[7] and our Risk Quantification Procedure.

The BCR is the ratio of investment benefits (mitigated risk) in a given year compared to the cost of the investment if undertaken in 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 (expected asset life) as the annuity period. This can be expressed as the following:

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

$$BCR = \frac{Benefit_{first\ year}}{Annualised\ Cost} = \frac{LoC \times CD\ \times CoC \times \left(PoF_{(Cond)existing} - PoF_{(Cond)new}\right)}{EAC}$$

An investment is justified economically when the BCR is greater than 1.0. This is equivalent to the asset being at or past the optimum time to invest, as shown in Figure 8.

Projects with BCR's less than 1.0 should not proceed unless there are qualitative reasons that justify the projects. This is out of scope of this model.

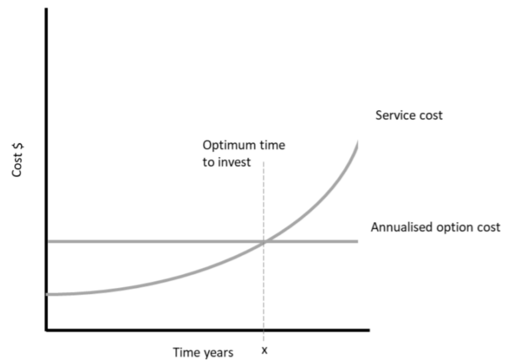

Figure 9: AER Optimal Investment Timing Example

The model is applied over a user defined time period. 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 BCRs are calculated for determining the investments in the new forecast year.

[7] AER, Industry practice note – Asset replacement planning, 25 January 2019