

Guidance document

AER augmentation model handbook

November 2013

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# Introduction

1. This handbook sets out the Australian Energy Regulator’s (AER) augmentation model (augex model). The augex model is intended for use as part of the AER’s assessment of the regulated services provided by electricity network service providers (NSPs). Capital expenditure (capex) undertaken by NSPs can be grouped into several distinct categories which include augmentation (or reinforcement), replacement, connections and non-system expenditure. The augex model is implemented as a series of Microsoft Excel spreadsheets developed for the AER to benchmark augmentation capex. The AER has determined that the augex model is best targeted to DNSPs initially. For the immediate future the AER will continue to undertake detailed investigation of TNSP capital expenditure proposals as those proposals tend to be supported by substantial detailed engineering investigation and analysis.
2. This handbook provides:

* the background and context for the augex model
* an explanation of the use of the model
* guidance on how particular network circumstances may be modelled.

1. This handbook is a guide for technical and non-technical staff of the AER and NSPs who may need to familiarise themselves with the augex model and its principles, or be involved in the application of the augex model.
2. This handbook is structured as follows:

* section 2 provides background and context to NSP’s capital expenditure and augmentation, summarising the major expenditure categories and their drivers, and the relationship to augmentation modelling within this mix
* section 3 introduces augmentation modelling, providing an overview of augmentation and explaining how it can be modelled for regulatory purposes
* section 4 details the AER’s augex model, summarising its form, and its input and outputs
* section 5 addresses questions which have arisen about the application of the augex model
* Appendix A provides more comprehensive reference material on the augex model.

# Categorising expenditure and the augex model

1. This section provides an overview of the various capex categories, indicating where the augex and repex models apply.
2. At its most aggregate level, NSPs’ capex can be considered in two broad categories that reflect the role of the assets:

* System capex, which broadly covers investment in assets in the "field" i.e. those assets that constitute the physical network that transports electricity
* Non-system capex, which broadly covers investment in assets that support these system assets out; for example, offices and equipment, central control facilities, plant, vehicles, and tools.

1. System capex is the major proportion of a NSP's capex, and is also the focus of the AER’s augex model.
2. System capex can be further disaggregated into categories that reflect the primary driver of the need to invest in the network. At the highest level, the primary drivers can be considered in terms of two forms:

* Demand-driven system capex, which is associated with investing in system assets to account for changes in the demand for electricity
* Non-demand driven capex, which is associated with other reasons for investing in system assets, most notably the condition of the existing assets or their environment.

1. The augex model is aimed at elements of the demand-driven capex. The repex model is aimed at elements of the non-demand driven capex.
2. Demand-driven system capex can be divided further into two forms:

* capex to connect customer to the network, or change their existing connections
* capex to increase the capacity/capability of the existing network in order to maintain its performance in the face of increases in the demand for electricity.

The augex model is focused on the second of the above forms of demand-driven system capex, which is typically referred to as augmentation.[[1]](#footnote-1) The categorisation described above and its relationship to the augex and repex models can be viewed more simply in terms of the driver versus activity mapping shown in the table below.

Table 1 System capex categorisation and the relationship to AER models

|  |  |  |
| --- | --- | --- |
| Capex driver | Replacement | Additional assets |
| Demand driven: customer connection | Replacement of assets to facilitate the connection | Development of new assets to facilitate the connection. |
|  | Augex model | |
| Demand driven: augmentation | Replacement of asset with increased capacity | Development of additional network assets to increase the capacity |
| Non-demand driven | Repex model Replacement of assets with modern equivalent (similar service level) | Installation of new assets |

1. The augex model should be applicable to the majority of capex allocated to the AER augmentation category. There may be however some elements of this capex that are not appropriate for assessment through the augex model. Examples of these will be discussed further in Section 5.

It is also worth noting that the augex model is not intended for the assessment of capex allocated to the customer connection component of demand-driven system capex. This is primarily because connection capex is not a function of the state of the existing asset base. As such, the AER’s assessment of connection capex does not normally rely on this predictive tool.

# AER augmentation model

1. The previous section described the various categories of a NSP’s capex, the factors driving this capex, and the resulting activities that generate capex. This categorisation was used to explain where the augex model (and the similar tool for assessing replacement expenditure (repex) ‘the repex model’) can be applied.

In this section, we provide an overview of the technical aspects of augmentation in order to introduce the approach we have taken to modelling the associated capex in a regulatory context.

## Predicting augmentation needs

### Asset rating, demand and utilisation

1. The network assets that transport electricity will all have operating limits that define the maximum amount of electricity that they can carry. Operating an asset above this limit may have serious consequences, such as damaging or destroying the asset, damaging or destroying other assets connected to or in the vicinity of the network, and risking the safety of field staff or the public.
2. The limits can be due to a number of factors associated with transporting electricity, including thermal effects on the asset, and voltage and stability effects on the system. For example, a common limit relates to the heating effect that occurs as an asset carries electricity. These “thermal” limits are often called the asset rating. Typically, an asset will have a range of different ratings that are applicable to different situations.[[2]](#footnote-2)
3. Whether or not one of these thermal ratings defines the maximum amount of electricity that can be transported or this is defined by a voltage or stability limits depends on the network and system arrangements. For example, as electricity is transported over longer distances, the voltage drop along lines may be the limiting factor on how much electricity can be transported.
4. Asset utilisation, as we define here, at any point in time simply reflects the proportion of a limit being used at that time – i.e. the demand / thermal rating. The highest utilisation over a period therefore reflects the proportion of the limit that is used at the time of the maximum demand on the asset over that period.
5. It is also worth noting that, as there can be various limits for an asset, the utilisation is reflective of the basis of the rating. For augex modelling, we choose one limit type - a thermal rating - to provide a common reference to measure utilisation. The reason for this is discussed further in Section 5.

### Maximum asset loading, the utilisation threshold and augmentation

1. Typically, the need to augment a network does not coincide with the maximum demand on the asset reaching a limit under normal circumstances. Depending on the limit chosen to measure utilisation, the network arrangements, and applicable reliability standards, the maximum utilisation (or utilisation threshold) before an augmentation is required could be above or below this point.
2. For example, as the level of demand increases, it can become economic to have a portion of the capacity in the network that is only required when other parts of the network are out of service (i.e. standby capacity). In these situations, the remaining assets will be loaded to a greater extent, as the customer demand takes an alternative path through these assets. If this additional capacity did not exist, customer supplies would need to be interrupted to ensure assets were not loaded above their ratings – and the consequences noted above did not occur.
3. Importantly, this utilisation threshold will vary for similar assets – even those subject to the same reliability standard. This can occur due to the level of interconnection associated with an asset and operational considerations, as these factors affect how demand will be transferred around the network following the network outage.

### Forecasting augmentation expenditure

1. Many NSPs will use a model of some form to allow the NSP to forecast the loading of its assets in the future (the whole network is modelled in the case of TNSPs). These models can be used to assess various network outages, in order to confirm whether the loading of assets may exceed the limits and in what situations this will occur.
2. This analysis will inform the nature and scale of future constraints on the operation of the system, and for applicable states, whether or not reliability standards will be breached. This in turn informs whether or not additional capacity is required and further evaluations may determine the optimal form that that capacity should take.

Clearly, accurately predicting the optimal timing of an augmentation and the appropriate solution for individual assets is a non-trivial exercise, and can require extensive data and modelling techniques.

## Augmentation modelling for regulatory purposes

1. The aim of our augex model is to simplify the analysis of complex forecasting methods while still maintaining some ability at the aggregate level to allow for the main drivers of augmentation. The augex model also provides a benchmarking framework that complements the high level assessment approaches the AER can use to assess augmentation expenditure and the more forensic, detailed engineering reviews of expenditure conducted by the AER. Provided that the network under examination is disaggregated to a sufficient degree into similar activity groups, the augex model will provide a benchmark indication of an NSP’s approach to augmentation in each activity category. The AER will use the augex model initially as a screening tool to identify the sub-categories of expenditure which should be subject to more detailed examination. We may also use the augex model as a reference to set revenue at a future date as we continue to refine it and our assessment methodologies for augmentation capex.
2. The benchmarks for the NSP in question can be compared to both the historical activity for that NSP and that of other similar NSPs to identify departures from industry norms. This is a task which requires the exercise of both technical and economic judgement. Where the reviewer is satisfied that the NSP is operating at a point close to industry norms then it is more likely that the associated capital expenditure is justified. Where departures from the norms are determined then the reviewer should initiate further technical investigation to establish the reasons for the departures. To facilitate the development of industry norms the AER is gathering data from all NSPs. The AER intends to be open and transparent to the maximum extent practicable. Wherever practicable, we will make this data available for general use.
3. To achieve these benchmarking aims, similar to the repex model, assets are considered as populations rather than individuals. The model does not hold specific limits or attempt to assess specific constraints or solutions. Instead, it assesses aggregate capacity and expenditure levels, based upon aggregate planning parameters that can be used for benchmarking purposes.
4. In a similar way that the repex model uses the physical volumes of assets to represent the network, the augex model uses the physical volumes of capacity (i.e. MVA) to represent the network. The model uses asset utilisation as the primary measure for the internal driver for an assets augmentation i.e. the peak demand on the asset as a proportion of its capacity. This utilisation measure is forecast into the future in the model using the most relevant external driver: the growth in peak demand.

The model uses three planning parameters to prepare forecasts. The planning parameter used to predict the need for augmentation across the population is the utilisation threshold.[[3]](#footnote-3) The utilisation threshold defines the point when, on average, assets need to be augmented i.e. they will breach reliability standards or exceed the economic point of maximum utilisation.

For augmentation, an asset may be overloaded, but the capacity is not replaced with the same capacity. Instead, capacity is added to the existing level. Therefore, the number of units of additional capacity that needs to be added, if say, one unit is found to need augmenting is required to be defined in the model. The model uses the second planning parameter, the capacity factor, to serve this purpose.

The third and final planning parameter of the model is the augmentation unit cost. This unit cost represents the average cost for providing an additional unit of capacity to the network.

To improve the accuracy of this assessment approach, the model uses two techniques as follows:

* The model allows the network to be constructed from various network segments, each with their own set of planning parameters. This allows some level of disaggregation to capture different augmentation circumstances that could affect benchmarking. For example, where one part of a network (e.g. distribution feeders) could have a significantly different economic loading point or augmentation solution to another part of the network (e.g. sub-transmission lines).
* The utilisation threshold uses a probabilistic model to allow for the variation in threshold that may be expected, even within a network segment.

The augex model can be used to develop a volumetric or expenditure benchmark for augmentation. Developing volumetric benchmarks require benchmarks of the utilisation thresholds and capacity factors to be defined. Developing expenditure benchmarks requires benchmarks of all three planning parameters to be prepared.

It is worth noting that the forecast volume and expenditure do not have to reflect solely network augmentations. Provided the planning parameters used in the model reflect the effective contribution of non-network solutions and costs on the augmented capacity forecast by the model then non-network solutions should be inherently catered for.

**Sample size**

Having a sufficient sample size is important in statistical modelling (in this case, the augex modelling). At the 95 per cent confidence interval the implied accuracy of a normally distributed sample can be estimated by the formula ± 1/(n)1/2 - where n is the sample size. That is, the accuracy is inversely proportional to the square root of the sample size. Thus, when a category has few samples the accuracy is likely to be low. For a sample size of 10 units the accuracy is ± 32 per cent, for 100 units it is ± 10 per cent and, for 1000 units it is ±3.2 per cent.

1. Although adding sub-categories which have small sample sizes may aid in identifying areas for closer examination in a specific category, this benefit should be balanced against the effort required to document sub-categories. The excessive use of finely differentiated sub-categories should be avoided. Wherever possible, seek to maintain the sample size in the sub-category as large as is reasonably practicable.
2. The aim of the AER in applying this formula is not to quantify the accuracy of a particular sample with precision. Rather, the intention is to gain a sense of the likely accuracy of a particular sample. Note that this formula applies to samples which are normally distributed. However, a particular sample may not be normally distributed. It is a quirk of statistical sampling that a collection of samples of a population that is not normally distributed will, nonetheless, tend to be normally distributed. As an indicative measure then, the formula above is deemed to be suitable for the AER’s intended use of gaining a sense of the likely variance in a particular category.
3. Regardless, the point is simply that sample size is important in implying the likely accuracy bounds of a sample population. The AER will have regard to the sample size at the category and sub-category levels when forming a view as to likely accuracy of a completed model.

# AER augmentation model

1. This section provides a more functional overview of the augex model.
2. The content of this section provides a broad familiarisation with the augex model. For users of the model, Appendix A provides detailed reference material, including an explanation of the various worksheets within the model, where model inputs and outputs are contained, and how the model is run.
3. As discussed in Section 3, the augex model is a high-level model that forecasts augmentation (both in terms of additional network capacity and its associated expenditure) based upon the current utilisation of the NSP’s asset base and forecasts of peak demand growth. The key features of the augex model are:

* categorising the network to develop a network model
* model inputs and outputs
* augmentation algorithm.

1. These features are discussed in turn below.

## Categorising the network

### Network segments

1. The augex model represents a NSP’s network as a set of user-definable network segments. The segments represent the network assets that tend to be grouped together for assessing augmentation needs. Generally, this means that a segment would represent either a set of substations or lines.[[4]](#footnote-4)
2. As noted in section 3.2, this segmentation is required to reflect broad variations in utilisation thresholds and augmentation costs that will occur between different network components. This segmentation can assist both in the accuracy of the model and in its interpretation. In particular, this segmentation can assist when comparing findings between NSPs.
3. This form of segmentation is essential to capture variations between broad network types, such as sub-transmission substations and lines, and distribution substations and lines. However, it is often also necessary to capture variations within these network types.

### Grouping

1. The augex model requires each segment to be assigned to a more limited set of segment groups. These groups should generally reflect the broader segment types (e.g. zone substations).
2. The aim here is to provide a high-level framework, based upon the segment groups, to aid the analysis and presentation of results.
3. Individual network segments can be aggregated to a number of separate segment groups. The intention is that the NSP will suggest the individual network segments in each segment group but the AER will define the groups. As previously noted, using an excessive number of segment groups may be counter-productive if the resulting number of segments is small. In practice we expect that the segment groups and network segments will be determined almost exclusively by the topology of the network under examination so this issue will be self-determined.
4. The grouping proposed by the AER is shown in Table 2 for DNSPs. Table 2 is subject to variation by a Regulatory Information Notice issued for an annual reporting or a revenue determination purpose.
5. Table 2 DNSP Segment groups

|  |  |
| --- | --- |
| Group ID | Group |
| 1 | Sub-transmission lines |
| 2 | Sub-transmission substations (and switching stations) |
| 3 | Zone substations |
| 4 | HV feeders – CBD |
| 5 | HV feeders – urban |
| 6 | HV feeders – short rural |
| 7 | HV feeders – long rural |
| 8 | Distribution substations – CBD (excluding downstream LV network) |
| 9 | Distribution substations – urban (excluding downstream LV network) |
| 10 | Distribution substations – short rural (excluding downstream LV network) |
| 11 | Distribution substations – long rural (excluding downstream LV network) |

## Segment input data

1. For each network segment in the model, two types of input data are required:

* Asset status data
* Planning parameters.

### Asset status data

1. The asset status data is used to develop the future profile of asset utilisation for that segment. The input data covers the following:

* Asset utilisation profile snapshot – This data set represents a snapshot of the existing profile of asset utilisation for that segment for a particular year. The year of the snapshot represents the starting point for the forecast. Typically, this year will be the last year that actual asset loading information is available. The utilisation profile can be considered a vector, where each element of the vector represents the capacity of the assets in that segment at a particular utilisation level. The utilisations range from 0 to 151 per cent, based upon 1 per cent increments.

For our purposes, the capacity is set to reflect the thermal rating (in MVA terms) of the relevant network segment under normal circumstances. The utilisation represents the proportion of that capacity used at the time of the peak demand on the asset.

* Asset utilisation growth rate – For each segment, a growth rate is defined that represents the average annual compound rate of growth in utilisation over the forecast period, assuming the network is not augmented. It is anticipated that this growth rate will reflect the average growth in peak demand that is relevant for the assets contained in that segment.

### Planning parameters

1. The planning parameter input data is used to forecast the capacity added to the network and the cost of that capacity, based upon the future profiles of asset utilisation for that segment. Three planning parameters are defined for each segment as follows:

* Utilisation threshold – The utilisation threshold defines the utilisation limit when augmentation must occur. As with the repex model, the augex model uses a probabilistic algorithm to determine the amount of the existing network requiring augmentation. This algorithm assumes a normal distribution for the utilisation threshold. Therefore, two parameters need to be input to define the threshold, namely the:
* mean utilisation threshold
* standard deviation of the utilisation threshold.
* Capacity factor – Using the above utilisation threshold, the model calculates the amount of the existing network that will require augmentation. The capacity factor defines the amount of additional capacity that is added to the system. This factor is normally determined from historical data for similar projects by the NSP. This is our preferred approach. Where this information is not readily ascertained it may be derived from the normal practices of the NSPs network planners or from a conscious policy decision of the NSP to increment capacity in standard steps. (i.e. When upgrading a transformer a policy to go to the next standard capacity size.) For example, if *A* is the amount of capacity requiring augmentation then the capacity factor multiplied by *A* is the amount of additional capacity added to the network. As such, the capacity factor must be greater than zero.
* Augmentation unit cost – The augmentation unit cost is the cost per unit of capacity added to the network. The model uses units of $ per kVA added, which is equivalent to thousands of $ per MVA added.

## Outputs of the Augex tool

1. The augex tool takes the above inputs and produces the following outputs for each segment and each group.

##### Utilisation statistics and charts of the input utilisation profile

1. To aid in the appreciation of the asset base, the model provides summary information of the utilisation profile. This is presented at the segment and segment group level. These outputs provide information, including:

* total volumes of capacity and augmentation value
* proportions of the total network above various utilisation levels
* average utilisation and utilisation thresholds.

1. The model also provides summary charts of the utilisation profiles.
2. This type of information is helpful in rapidly understanding the nature of the asset base i.e. its utilisation and value. This information is also helpful when making comparisons of augmentation drivers between NSPs.
3. Importantly, this information only reflects the utilisation profile as input to the model. It does not account for any forecasts that may be simulated by the model.
4. 20-year augmentation forecasts
5. Based upon the input data, the model produces year-by-year forecasts of network augmentation for the following 20 years.
6. The forecasts prepared include individual segment forecasts and aggregated group forecasts.
7. The forecasts cover:

* capacity added (MVA)
* augmentation expenditure ($ millions)
* average utilisation - at the group level, the weighted average utilisation is calculated.

1. When calculating weighted averages at the asset group level, the total augmentation value of the relevant segment is used for the weighting.

## Augmentation algorithm

1. The augmentation algorithm is written as a Visual Basic for Application (VBA) array formula within excel. As such, provided excel is set to have calculations automatically updated, any alterations to inputs should result in the output forecasts being automatically updated. The user is not required to run any macros after the initial setup of the model (see section A.6).
2. The algorithm produces the 20-year forecast of both capacity added and expenditure for each segment. The figure below shows an overall flow chart of the algorithm.

Figure 1 Augmentation algorithm



1. The three elements of this algorithm are described in turn below.

### Capacity requiring augmentation

1. To calculate the amount of the existing capacity that will need to be augmented in each year, the model uses a similar probabilistic model as applied in the repex model.
2. As noted above, the augex model assumes a normal distribution for the utilisation threshold. For each segment, an “unconditional” probability density function can be generated from the mean and standard deviation, which are provided as inputs. The unconditional probability density function represents the probability that a unit of capacity will need to be augmented at any particular utilisation level, assuming we have just installed it at zero utilisation.
3. However, assuming the unit of capacity has survived to be utilised at its current level, a “conditional” probability density function can be generated to reflect these circumstances. The “condition” probability density function defines the probability that a unit of capacity in the segment will need to be augmented at a future utilisation level, given it has survived to be loaded to its current utilisation level.
4. For example, Figure 2 shows the "unconditional" probability density function for an utilisation threshold. This function represents the probability that an asset will be augmented at a specific utilisation, assuming the average utilisation threshold for this segment is 60 per cent - with a standard deviation of 10 per cent. The figure also shows the “condition” probability density function for a population of assets that are currently at a utilisation level of 55 per cent i.e. they have survived up to the utilisation of 55 per cent. The conditional probability density function indicates the proportion of those assets that will need to be augmented as the utilisation increases in the future.
5. Figure 2 Utilisation threshold probability distributions



1. To calculate the amount of capacity requiring augmentation in each future year, the model steps through the following for each utilisation element in the input utilisation profile:

* Step 1 - preparing a conditional probability function from the unconditional parameters, that reflect the utilisation in that element of the utilisation profile
* Step 2 - calculates the year-by-year increase in utilisation, based upon the input demand growth rate
* Step 3 - determine the capacity that must be augmented in each year, based upon the utilisation in that year (from Step 2) and the proportion given by the conditional probability function (from step 1).

### Capacity added

1. The above process calculates the existing capacity that requires augmentation in a given future year. To calculate the capacity that is to be added to the network in that year, the model multiplies the capacity requiring augmentation by the input capacity factor:

Capacity added = capacity requiring augmentation x capacity factor.

1. As it is feasible that this augmented capacity will also require augmentation later in the simulation period, the augmented capacity is fed back to the probabilistic algorithm above to determine whether additional capacity is required at a later data (see the feedback arrow in Figure 1).
2. The utilisation for the augmented capacity is defined as:

New utilisation = demand in the capacity requiring augmentation / (capacity requiring augmentation + capacity added).

1. The total capacity added following this feedback process is provided as an output of the model.

### Expenditure forecast

1. To calculate the expenditure in a year, the model simply multiplies the total capacity added in that year (i.e. the output of the above calculations) by the augmentation unit cost:

Expenditure = capacity added x augmentation unit cost.

# Model guidance and clarifications

1. During discussion with NSPs, a number of queries have arisen in association with modelling particular circumstances within the augex model. This section discusses common matters raised by NSPs and provides some further guidance on how and why particular network circumstances could be modelled.
2. Note that the augex model is not a substitute for the detailed project planning processes undertaken by an NSP. The primary roles of the model are to develop an awareness of the cost centres within a network and to facilitate comparisons of similar activities by different businesses. This will promote understanding of the consequences of different technology choices and work practices. It will also help to inform understanding of the impact of geographical and operating environment differences.
3. The augex model is best used in circumstances where an NSP has yet to undertake detailed planning. By looking at potential projects as a portfolio using statistically based techniques, the AER will be better able to test the need and timing of proposed projects. Where detailed work has been carried out by an NSP planning a specific project, that work should still be subject to specific review and analysis.

### The preferred use of N thermal rating

1. As discussed in 3.1, a range of limits (thermal, voltage and stability) can drive the need for augmentation, depending on particularly circumstances. And in some circumstances, the maximum limit is defined by outage conditions rather than the normal condition.
2. The augex model can allow any limit to be used to measure utilisation. However, for the AER assessment, utilisation is set to be measured relative to the thermal rating under normal (N) conditions.

A common question from NSPs is why, particularly when voltage or stability limits may be a more pressing concern for rural networks and typically N-1 conditions drive the need for augmentations.

The reason for this is to ensure we have a common reference point between NSPs to compare the planning parameters, particularly the utilisation threshold. In this regard, the N thermal rating of an asset is relatively independent of the network arrangements. Furthermore, the N thermal rating provides a meaningful measure of the physical capacity limit of that asset that ideally we would like to be able to use. Consequently, the N thermal rating is considered to be the most suitable limit for the regulatory assessments intended for the augex model.

In contrast, if we measured each NSP segment by its most pressing limit then this would result in all planning thresholds being calibrated to 100 per cent say. This may still be helpful for intra-company benchmarks i.e. by comparing an NSP from one period to the next. However, it would not provide useful parameters for benchmarking between NSPs. Furthermore, it does not provide a simple gauge of how much redundant capacity must be held under normal circumstances.

Clearly, this is not to say that one NSP can be arbitrarily benchmarked against another. Instead, like other benchmarking techniques we are applying, benchmarking through the augex model may need to consider the environmental factors not allowed for within these assumptions.

The segment groups we have defined should allow for this to some degree. For example, urban distribution feeders are classified separately from rural feeders, partly because of these perceived differences. Nonetheless, benchmarking via some other metric that captures transportation distances may also be required to normalise for these effects.

### The HV feeder trunk section assumption

Typically, a HV feeder supplies customers distributed along its length and is formed from many sections and spurs that may have different thermal ratings. As such, the utilisation changes along its length and the augmentation needs may differ along its length, depending on the circumstances at that location.

The augex model can represent feeders in numerous ways; however, we have simplified the modelling so that only the initial trunk section of the feeder is represented. That is, the peak demand and thermal rating of the first section of feeder emanating from a zone substation is used to calculate the utilisation and measure augmentation needs.

Some NSPs have questioned whether this simplification is valid as many feeder augmentations will occur downstream of the trunk section and their need may not be related to the utilisation of the trunk section.

We recognise that this may be a significant simplification. However, we are concerned that not all DNSPs have their distribution networks modelled in sufficient detail that a more complex feeder model can be prepared without imposing significantly more effort and cost on some DNSPs. In the absence of more compelling evidence, we believe it is reasonable to assume that the level of augmentation along the feeder will have some relationship to the utilisation of the trunk feeder section, and therefore, this assumption is appropriate for the intended use of the augex model. This assumption is in line with our experience that many DNSPs have employed similar trunk feeder models to produce medium- to long-term forecasts.

We will however continue to investigate this issue, with a view to develop the feeder representation in the augex model in the future. In the meantime, if considered necessary, we will investigate the detailed HV feeder forecasting undertaken by DNSPs to prepare their proposal forecasts.

### Allowing for non-trunk section augmentations in data preparation

Given the trunk feeder assumption, a number of DNSPs have queried how HV feeder augmentations on other sections of the feeder should be allowed for when preparing planning parameters.

As these augmentations do not add to the segment capacity (i.e. trunk feeder capacity) they should only be seen as additional expenditure for the relevant segment in order to determine the augmentation unit cost. These types of augmentations would not result in any additional capacity for that segment.

These types of augmentation will result in some uplift in the unit cost that reflects the relative proportion of new feeders and trunk upgrade compared to the non-trunk section augmentations. However, for augmentations that enable a higher utilisation of the feeders (e.g. cross feeder ties) then it would be expected that this benefit will be reflected as an increase in the utilisation threshold. We consider that although this may indicate a higher relative cost than other networks with less interconnection, this will better represent the true cost of the network. Thus, although the NSP may need to provide an explanation for the higher costs, the improvement in other planning parameters should demonstrate an offsetting benefit. If a similar approach to augmentation is adopted by other NSPs then the equivalent costs are likely to be comparable.

### Meshed networks and loops

The meshing and looping of circuits, which typically may occur at sub-transmission and above, can mean that some lines in a segment are heavily utilised under N conditions while others are very lightly utilised. However, under the critical N-1 condition the utilisation may change considerably.

For example, assume a balanced loop of three circuits feeding two substations. Under normal conditions the middle circuit will have zero utilisation. However, under the critical N-1 condition, the utilisation of this circuit could increase considerably.

NSPs were unclear how to model these circumstances and whether they may affect the model forecast.

In our view, the averaging that should occur due to the aggregation of assets in a segment should even out the effects of these variations. Therefore, unless the NSP can perform some analysis to show that additional segments are required (e.g. by demonstrating that the difference would be material on the weighted average of the planning parameters derived for a more complex segmentation) then we do not see a need to define additional segments in order to capture the effects on different circuits.

### The implications of long project lead times

The augex model assesses capacity needs in a year and calculates expenditure for that year. In effect, the model uses an “as commissioned” approach to forecasting expenditure i.e. expenditure is assigned to the year that the additional capacity would be commissioned.

NSPs have questioned how they should treat projects with longer lead times, where significant levels of expenditure may need to be incurred in years before the project is commissioned. This can be material for larger projects, particularly at sub-transmission and above.

As the model forecast expenditure on an “as commissioned” basis, the expenditure being recorded to determine the unit cost planning parameter must be provided on that basis. That is, historical expenditure used to calibrate the unit costs parameters or forecast expenditure used to infer a future parameter must be on that basis.

If an “as incurred” expenditure basis is required for regulatory purposes then this would need to be calculated from the augex model output via some form of post-processing of the output forecast. For example, representative expenditure “s-curves” could be determined and then used to transform the “as commissioned” forecast to an “as incurred” basis as a separate exercise.

### Weather-correcting the actual peak demand

The utilisation profile in the augex model represents the amount of capacity at increments of utilisation. The utilisation is set to reflect the historical peak demand divided by the capacity. Often, the actual peak demand is sensitive to the weather conditions that have occurred around the time of the peak demand. Therefore, for their own planning purposes, NSPs may “weather correct” the peak demand to transform it to some standard weather conditions in order to then assess the extent of constraints for these standard conditions.

NSPs have queried whether the utilisation used in the augex model should be weather corrected and, if so, to what standard conditions.

We intend to collect actual peak demand and capacity in order that it can construct the utilisation profiles. As part of this process, we will consider the implications of weather correcting the actual peak demand through its review of the NSPs maximum demand forecast.

Noting the comments above on the need for a common reference point between NSPs making comparisons, if considered material, the actual peak demand will be transformed to “average” weather conditions (i.e. an equivalent 50 per cent probability of exceedance condition) for preparing the utilisation profiles that are input into the model.

### Augmenting one segment to address constraints in another

The segmentation in the augex model disaggregates the network into lines and substations, typically with a further disaggregation into voltage levels.

At times, the optimal augmentation will involve an augmentation to one of these types of segment, but it will be due (in whole or in part) to a constraint in another segments. For example, additional HV feeders may be constructed to alleviate capacity needs associated with the sub-transmission level.

NSPs have queried how this is allowed for in the augex model and its use of segmentation.

It is important to stress that the analysis in the augex model is done at the segments level and there is no inherent interrelationship between segments. Therefore, if the model determines a capacity need in a segment, the model assumes that these will be alleviated by an augmentation to that segment when preparing the forecast.

This means that care is needed when preparing and assigning project capacity and cost data to segments. This historical or forecast project data is required to calibrate the model planning parameters to the respective historical or forecast periods. The correct project assignment should reflect the segment type that drove the need for the project, not the segment type that the project resides in.

In situations where the project was materially driven by needs in different segments then the project capacity and cost may need to be split between the relevant segments. This must however ensure that there is no double counting of capacity and costs between segments.

In situations where project capacity and costs have been assigned to other segments, it will be important that the NSP ensures it is clear where this has occurred and why. When providing data to the AER should include in the commentary an explanation where these situations have arisen.

### Unmodelled augmentations

The augex model assesses augmentation needs based upon the existing utilisation of the network and whether this is forecast to exceed a threshold.

Some NSPs have noted instances of projects that may be considered augmentation projects but may not be assessable using the augex model. As these projects can vary widely and often particular to a NSP’s circumstances, it is difficult to discuss all specific cases in a handbook such as this. Nonetheless, in deciding whether a project (or its driver) should be allowed for directly through the augex model then it is important to consider whether the timing and form of the project is directly related to the peak demand and capacity of the existing network assets. That is, if the assessment of the need, timing and solution, via the NSP’s processes, would involve some form of analysis or consideration of the loading of existing assets around the peak demand time and the comparison of this loading against some form of network limit that defined the capacity of the network then this would typically be allowed for in the augex model. As noted, in 3.1, this should encompassed the all typical network loading limits covered by augmentation planning studies, including thermal, voltage and stability limits.

Exceptions to this however may include:

* fault level mitigation works, which by their nature are not directly related to the peak loading of assets
* augmentations to manage low demand situations
* augmentations driven largely by the connection of generation and the ability of the network to export the supply from the generation.
  + - * 1. Appendix A - Augex model reference manual

1. This Appendix provides a detailed reference to the augex tool to support the descriptions in the main body of this document. This reference describes the contents of each sheet within the augex tool. The purpose of this appendix is to provide more detailed information that may be relevant to users of the augex tool.
2. In the descriptions below, the light blue shading indicates that data in these cells is input by the user.
3. It is important to note that care should be applied when using the tool, as the input of erroneous data or altering the structure may result in unreliable results. This may not be easily identifiable from the outputs.

Data Input sheets

Sheet name: Tables

1. This sheet holds the data that is required to initialise the augex model, as follows:

| Title | Range | Description |
| --- | --- | --- |
| Asset group names | A2:B13 | Column B of this table contains the names for each of the 12 segment groups. These names generally represent asset classes, and can be input by the user. The ID in column A represents the number that is input into the appropriate cell in the "Asset data" sheet (see description below). |
| Now | B17 | This parameters represent the year used to develop the utilisation profile. The 1st year of the forecast will be the year after this. |

Sheet name: Asset data

1. This sheet holds the input data that is required to represent the DNSP's asset base (section 4.2):

| **Title** | **Range** | **Description** |
| --- | --- | --- |
| ID | A21:205 | This parameter is used to define the segment group for the network segment. The ID should be the appropriate number of the asset group defined in the asset group names on the "Tables" sheet. |
| Segment group | D21:D205 | This is the name of the segment group linked to the ID in Column A. This is generated internally by the model. |
| Network segment | E21:E205 | This is the name of the network segment - any name can be chosen by the user. |
| Unit cost | F21:F205 | This is the augmentation unit cost for the segment in $('000) per MVA. |
| Capacity factor | G21:G205 | This is the capacity factor for the segment. This should be a number greater than zero. |
| MD growth per annum | H21:H205 | This is the per annum maximum demand growth rate for the segment. This should be input as a percentage, i.e. 10 represents 10%. |
| Utilisation threshold | I21:J205 | This is the utilisation threshold for the segment. Column I holds the mean life and Column J holds the standard deviation. These should be input as a percentages, i.e. 10 represents 10%. |
| Aug method | I21:I205 | This parameter is used to define the augmentation algorithm applied to generate a forecast at segment level.  At this time, only 1 can be used. This represents the probabilistic algorithm, using a normal distribution. |
| Utilisation profile | L21:FG205 | This holds the utilisation profile for each segment, in terms of capacity units (MVA). |

Output sheets

Sheet name: Utilisation profile summary

1. This sheet provides a summary of the utilisation profile. Rows 6:18 provide summary results at the segment group level. Rows 21:205 provide similar results at the individual segment level.

| Title | Range | Description |
| --- | --- | --- |
| Capacity | Column F | The total capacity within the segment or segment group. |
| Unit cost | Column G | The unit cost of the segment - transferred directly from the "Asset data" sheet. |
| AC (Aug cost) | Column H | The total augmentation cost of the segment or segment group. Calculated as capacity x unit cost, and given in $million. |
| Prop total | Column I | The proportion as a percentage (calculated by total augmentation cost) of that segment or group to the total augmentation cost of the network. |
| Rank total | Column J | The ranking of that segment or group (by total augmentation cost) compared to other segments or groups i.e. a ranking of 1 will have the greatest total augmentation cost. |
| Prop cat | Column K | The proportion as a percentage (calculated by total augmentation cost) of that segment to the total augmentation cost of the associated group. |
| WARU | Column M | The weighted average remaining utilisation of the segment or group, using the total augmentation cost as the weighting. |
| WAUuth | Column O | The weighted average utilisation threshold of the segment or group, using the total augmentation cost as the weighting |
| WAU | Column Q | The weighted average utilisation (as a percentage of the utilisation threshold) of the segment or group, using the total augmentation cost as the weighting. |
| AC of utilised assets | Columns W:AA | The proportion of assets (by augmentation cost) in 5 bands of utilisation. |
| Proportion of utilised assets | Columns W:AA | The proportion of assets (by percentage) in 5 bands of utilisation. |
| Utilisation asset bands | W4:Z4 | The parameters used to define the utilisation bands for the above two outputs. These are defined as a proportion of the utilisation threshold. |
| Group utilisation threshold ranges | AG6:AI17 | The range of thresholds in a group:  Maximum - column AG  Minimum - column AH  Average - column AI |

Sheet name: aug forecast

1. This sheet provides the results of the augmentation forecast. Rows 6:18 provide summary results at the group level. Rows 21:205 provide similar results at the individual segment level.

| Title | Range | Description |
| --- | --- | --- |
| Augmentation capacity added forecast | Columns AY:BR | Provides the year-by-year forecast over a 20 year period of the capacity (MVA) added to the network .  Row 19 shows the total capacity added as a percentage of the total capacity of the network. |
| Weighted average utilisation | Columns BS:CM | Provides the year-by-year forecast over a 20 year period of weighted average utilisation.  Row 19 shows the weighted average utilisation of the whole network as a percentage of the weighted average utilisation threshold of the whole network. |
| Weighted average remaining utilisation | Columns CN:DH | Provides the year-by-year forecast over a 20 year period of weighted average remaining utilisation i.e. the difference between the utilisation threshold and the utilisation.  Row 19 shows the weighted average remaining utilisation of the whole network as a percentage of the weighted average utilisation threshold of the whole network. |
| Replacement quantity forecast | Columns DI:EB | Provides the year-by-year forecast over a 20 year period of the augmentation capex ($millions).  Row 19 shows the total augmentation capex as a percentage of the total augmentation value of the network. |

Chart sheets

Chart sheet name: utilisation profile chart

1. This chart sheet provides two charts - one stacked and one unstacked - of the utilisation profile at the segment group level:

Chart sheet name: Forecast Ch1

1. This chart sheet provides three charts of the augmentation forecasts:

* The stacked bar chart at the group level, showing the year-by-year augmentation expenditure forecast ($ millions).
* An z-y plot, showing the forecast weighted average utilisation for each group and the weighted average utilisation of the total network.
* The un-stacked bar chart at the group level, showing the year-by-year augmentation expenditure forecast ($ millions).

Chart sheet name: Forecast Ch2

1. This chart sheet provides one chart of the augmentation expenditure forecast for each group, represented as a 3-dimensional bar chart showing.

Internal sheets

1. The model also includes three other sheets that are used for internal purposes i.e. producing charts and aiding with the calculations. These sheets are called:

* Utilisation profile (Inst)
* Utilisation profile (RL)
* Utilisation profile

1. These three sheets have the same structure, and as the names suggest, are used to hold different representations of the utilisation profile. The user is not required to interact with these sheets, and as such, they are not described in detail here.

Macros and setting up a model

1. When setting up a model of an DNSP using the augex tool, the following process should be followed:
   1. Set the required initialisation data in Sheet: Tables (i.e. group names, starting year)
   2. Input segment data in Sheet: Asset data. Blank rows can be left between asset categories to help with the visualisation. However, the following two point are important:
      1. segments should not be placed below the coloured table
      2. rows (or columns) should not be inserted or deleted.
   3. The macro "initcalcs" should be run. This macro calculates the number of segments being used and automatically sets up other calculation sheets.
2. The model should now be able to produce augmentation forecasts. Note however, if additional segments are added below the final segment on the asset data sheet, then the macro "initcalcs" should be run once again.

Additional sheets can be added as required; for example, to contain working calculations and comments. A sheet called “Notes” is also included for these purposes.

1. This type of capex is also known as reinforcement. [↑](#footnote-ref-1)
2. For example, a transformer may have various name plate ratings that reflects idealised design criteria; it may also have various long-term cyclic ratings that reflect the expected load pattern and the effect this has on the heating and cooling of the transformer; and it may also have shorter-term emergency ratings that may be useable in certain situations. [↑](#footnote-ref-2)
3. The utilisation threshold is analogous to the replacement life used in the repex model. [↑](#footnote-ref-3)
4. Note the difference here to the repex model, which defines individual categories at an asset level. As such, it may be expected that the augex model will have fewer individual network segments than the repex model will have asset categories. [↑](#footnote-ref-4)