TELSTRA CORPORATION LIMITED

Telstra's Efficient Access Model

Model Documentation
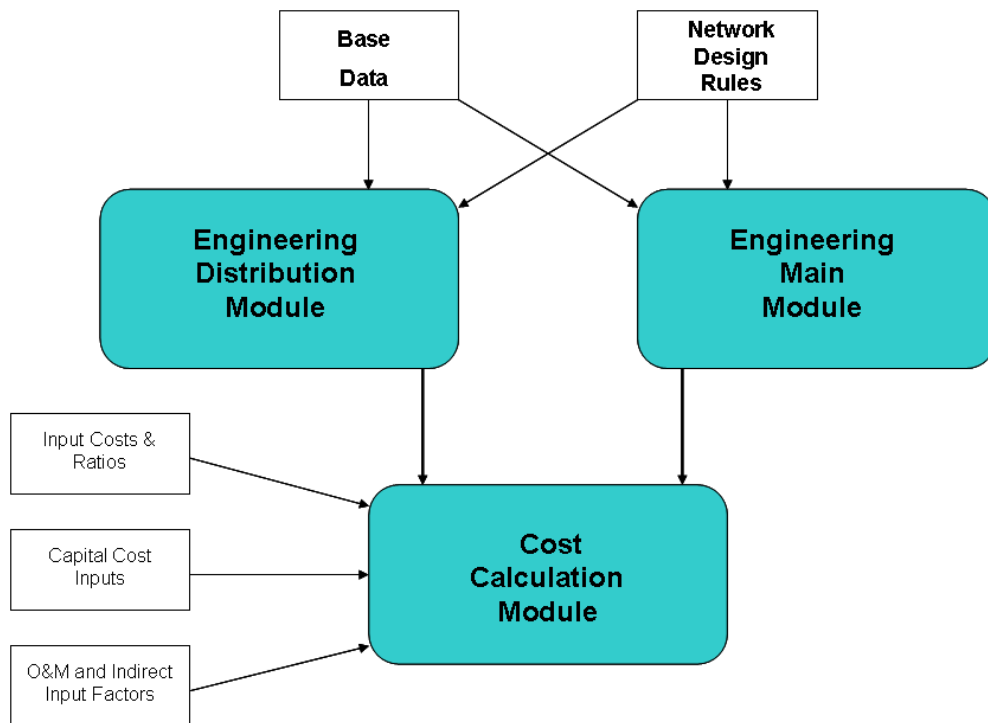

6 August 2008

Contents

A   Model Overview

1. The Telstra Efficient Access (TEA) model has been constructed for the purpose of calculating a reasonable estimate of the Total Service Long Run Incremental Cost (TSLRIC) of providing the Unconditioned Local Loop Service (ULLS) in metropolitan areas of Australia, referred to as Band 2 areas.

2. The model estimates the cost a new entrant would incur to supply the ULLS product. Since ULLS is provisioned over the Customer Access Network and defined as unconditioned copper facilities, the TEA model estimates the cost of a forward-looking, efficient access network comprised of unconditioned copper facilities. The model is based on real data, it utilises the actual locations of customers, pillars and exchange buildings. This allows accurate and realistic estimates of today's forward-looking costs. The model adheres to the efficiency requirements of the ACCC's TSLRIC pricing principles by adopting best-in-use equipment and efficient, best-practice engineering standards, construction techniques and placement practices and procedures. A fuller discussion of the principles underlying the TEA model is provided in the *TEA Model Overview*.

3. The model is comprised of three modules, each of which relies on a set of inputs. There are the two engineering modules, one for the distribution network and one for the main network. These modules use best practice network engineering design rules together with base data extracted, translated and loaded from Telstra's Cable Plant Records for each of Telstra's Band 2 exchanges to determine an optimised network design for the distribution and main networks. The output of these modules is the volume of plant, labour and equipment required to deploy the efficient access network.

4. Both the Distribution and Main Modules of the model run at the level of individual exchanges service areas (ESAs), with results for multiple ESAs being the sum of the results for individual ESAs. Therefore, the model can be run for: all Band 2 ESAs, any combination of Band 2 ESAs or for a single Band 2 ESA. When the model is run for multiple exchanges, the plant and equipment volumes are calculated and saved one ESA at a time. After the output for one exchange is saved, the next exchange is processed through the engineering modules overriding the data and calculations for the exchange that was previously processed. This approach is required to limit the size of the engineering modules to a level that can be accommodated in Excel. Although the detailed engineering data for each exchange is not retained by the model, it can be retrieved for any Band 2 exchange by opening the stand-alone main and distribution engineering modules and processing each exchange separately. This feature allows the model to be reviewed and audited for all Band 2 ESAs.

5. The output of the engineering modules feed into the Cost Calculation Module. The Cost Calculation Module applies the input costs and ratios to the plant and equipment volumes produced by the engineering modules to calculate the total investment cost associated with the efficient access network. The Cost Calculation Module then converts the investment cost into an annual capital cost using the capital cost inputs. The Cost Calculation Module also calculates operating and maintenance (O&M) expenses and indirect costs using input factors determined from separate studies. Finally, the Cost Calculation Module sums the relevant costs – annual capital costs, O&M expenses and indirect costs – to arrive at the total annual cost of the efficient access network. This total annual cost is then divided by 12 to derive a monthly cost.

6. The structure of the model is illustrated in Figure 1 below.

Figure 1: TEA Model Structure

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┌──────────┐              ┌──────────┐
│   Base   │              │ Network  │
│   Data   │              │ Design   │
│          │              │  Rules   │
└────┬─────┘              └────┬─────┘
     │      ╲            ╱      │
     │       ╲          ╱       │
     ▼        ╲        ╱        ▼
┌─────────────────┐  ┌─────────────────┐
│   Engineering   │  │   Engineering   │
│  Distribution   │  │      Main       │
│     Module      │  │     Module      │
└────────┬────────┘  └────────┬────────┘
         │                    │
┌──────────────┐             │
│ Input Costs &│╲            │
│    Ratios    │ ╲           │
└──────────────┘  ╲          ▼
                   ▼  ┌─────────────────┐
┌──────────────┐     │      Cost       │
│ Capital Cost │────▶│  Calculation    │
│    Inputs    │     │     Module      │
└──────────────┘     └─────────────────┘
                   ▲
┌──────────────┐  ╱
│O&M and Indirect│╱
│ Input Factors │
└──────────────┘
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7.   The remainder of this document explains in detail the three different modules of the model.

B   Engineering Distribution Module

8.   The engineering architecture of the distribution network is modelled in the Engineering Distribution Module. This module uses best practice engineering design rules together with base data extracted, translated and loaded from Telstra's Cable Plant Records to design an optimised copper distribution network for the supply of the ULLS. The distribution network architecture used in the model is illustrated in Figure 2 below. The output of the Engineering Distribution Module is a list of the amount of labour, plant and equipment required to deploy the optimised distribution network. The Engineering Distribution Module contains four worksheets: *Distribution – Input, Distribution – Detail, Distribution – Collapsed* and *Distribution – Summary*. The following section describes each of the worksheets.

B.1   Description of Worksheets

B.1.1   Distribution – Input

9.   *Distribution – Input* contains the key design criteria for the distribution network. These criteria are taken from the "Access Network Dimensioning Rules" ("Dimensioning Rules") developed by the Telstra engineering department. The Dimensioning Rules are designed to reflect the efficient engineering best practices and procedures for deploying a new ULL network. Many of these rules can be adjusted by the user in the input sheets of the user interface to the models[1]. The rules and model parameters that are included in the *Distribution – Input* worksheet are:

- the identifier that specifies whether a tapered or non-tapered design is used in the model run (1 designates a tapered design and 2 designates a non-tapered design) (User Adjustable-UA);

- the distribution cable fill that is used to design the copper cable network in the distribution module (UA);

- the range of customers per square kilometre that are used to categorise DAs by density zone;

- the maximum haul length for each size of distribution cable, which is used to determine the maximum distance between cable joints (UA);

- the maximum allowable distance between pits in the distribution network (UA);

- the percentage of occurrences that one through four customers are served from a single pit (UA);

- the size and capacities for pillars and pillar terminal strips used in deploying the distribution network;

- the size of various conduit configurations used in deploying the distribution network; and

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[1]   Changes to these rules or parameters should be made in the inputs sheets incorporated into the user interface to the model. Input changes made directly into this module will not flow through to the Cost Calculation Module or results.

- the size of the terminal strips and cables that are used in deploying the distribution network[2].

B.1.2 Distribution – Detail

10. *Distribution – Detail* contains the base data that has been extracted from Telstra's Cable Plant Records. This data is presented at the level of individual structure points within distribution areas (DAs). This worksheet also calculates the total length of each type of cable that will be required to serve customers in the DA, the number of cable joints[3], the quantity and size of all building terminals in the DA including the length of cable required to connect building terminals to the network and the number and length of all 2 pair lead-ins required to connect customers to the network[4]. This worksheet also performs a number of calculations that provide the basis for the plant quantity calculations undertaken in the *Distribution – Collapsed* worksheet.

B.1.2.1 Base Data

11. As noted above, the *Distribution - Detail* worksheet imports data from Telstra's records that are necessary to design an efficient network for providing ULL services. The data are extracted by structure point. A structure point is a physical component of the network (i.e. pillar, pit, manhole, lead-in or elevated joint). Each structure point is identified by a number. The path that the distribution network takes from the customer premise to the pillar is determined by tracing existing cable routes through the various structure points. The base data for each structure point is identified in the first 11 columns of the *Distribution – Detail* worksheet and the headings for each of these columns are shaded in grey. The data extracted for each structure point are:

- ESA - The designation for the exchange in which the structure point resides;

- DA# - The designation of the distribution area in which the structure point resides: also the number for the pillar or cabinet to which the structure point will ultimately be connected;

- Segment Length – The distance between the current structure and the next closest structure on the route back to the pillar;

- Total Distance to the Pillar – The sum of all the segment lengths that would be required to connect the current structure to the serving pillar or cabinet;

- Lead-ins Served by Structure – The number of two-pair lead-ins served by the current structure;

- Type of Structure - The designation for the type of structure referenced (i.e. pit, manhole, or lead-in);

- Building Terminal – Identifies whether the structure is used to serve a building terminal (Y) or does not serve a building terminal (N);

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[2] Note that the Telstra only provides the strip used to connect the cables to the building terminal. The building terminal is supplied by the building owner.

[3] The term joint always refers to the joining of two pairs of wires, so that the joining of two 100 pair cables requires 100 joints.

[4] Building terminals refer to multi-dwelling residences and commercial premises, which are connected to the network using lead-ins that are sized to meet the demand requirement of the building terminal. Single dwelling premises are connected to the network using 2 pair lead-ins.

- Building Terminal Size – The size of the existing building terminal at a location or structure point;

- Current Structure Number – The number used to identify the current structure point;

- Next Structure Number – The number used to identify the next structure point to which the current structure is connected on the path back to the pillar or cabinet; and

- Trace Level – The trace level provides an aid in identifying the route from any structure point to the pillar serving that structure.

12. This base data allows the model to identify the efficient path from the customers' premises to the serving pillar. These efficient paths are then combined to design an efficient distribution network for every distribution area.

B.1.3 Distribution – Collapsed

13. *Distribution – Collapsed* combines some of the data identified in *Distribution – Detail* worksheet to derive composite data by DA. The worksheet also imports some additional base data from Telstra records. This data is presented at the level of the individual DAs. The worksheet also calculates the volumes of conduit length, distribution pits, pillars, joints at pillars, joints past the maximum haul distance and pit extensions required for each DA. Many of these volume calculations rely on values calculated in the *Distribution – Detail* worksheet.
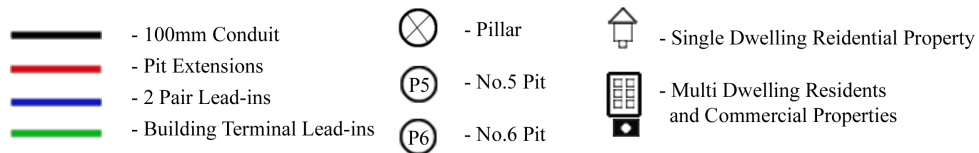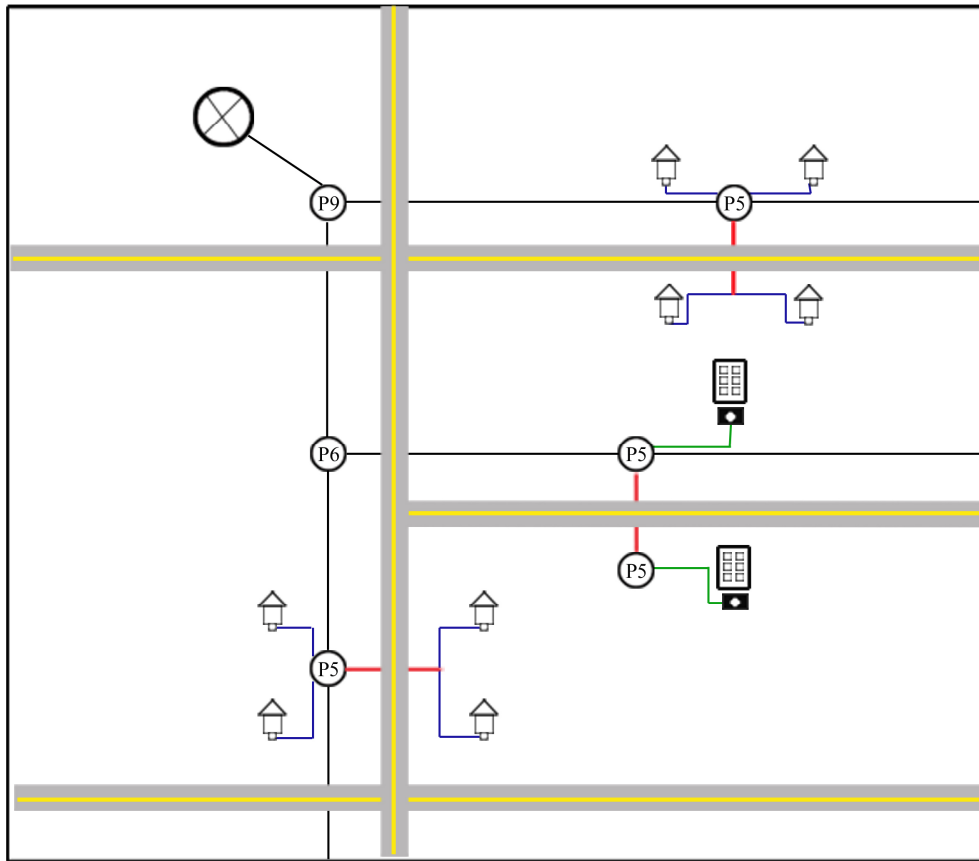
B.1.3.1 Base Data

14. As noted above, the *Distribution - Collapsed* worksheet imports additional data from Telstra's records that is compiled at the DA level. The base data for each DA is identified in the first 4 columns of the *Distribution – Collapsed* worksheet and the headings for each of these columns are shaded in grey. The data extracted for each distribution area are:

- ESA - The designation for the exchange in which the structure point resides;

- DA# - The designation of the distribution area in which the structure point resides: also the number for the pillar or cabinet to which the structure point will ultimately be connected;

- Demand Served by Pillar – The total number of services in operation (SIOs) within the distribution area; and

- Area (sq. km) – The total area served within the distribution area stated in square kilometres.

15. The SIO data by DA is used in determining the number of main cable pairs that will be connected to the pillar. This information is used to size the pillar interface with the main network. The area information is used to compute a density index for each distribution area based on customer density within the area.

B.1.4 Distribution – Summary

16. *Distribution – Summary* presents the volume of plant, labour and equipment required in the distribution network summarised to the level of the ESA. Where appropriate the data is compiled by density range.

17.	The plant, labour and equipment in the *Distribution – Summary* worksheet is broken down into the following categories:

- Length of Distribution Cable by Cable Size (see Section B.2);

- Number and Size of Cable Joints (see Section B.3);

- Number of Pillars (See Section B.4);

- Number of Pillar Terminal Strips (see Section B.5);

- Length of Distribution Conduit (including Pit Extensions) by Density Range and Conduit Configuration (see Section B.6);

- Number of Pits by Density Range and Pit Type (see Section B.7);

- Number of Building Terminals by Size (See Section B.8);

- Length of Building Terminal Lead-ins (see Section B.9); and

- Number and Length of 2 Pair Lead-ins (See Section B.10).

18.	For continuity purposes, all the calculations used in determining the quantities for each category of facilities identified above are addressed in a single subsection. The calculations for many of the network components span a number of worksheets. For example, the calculations required for determining the number and types of pits required in an exchange are located on three separate worksheets. The *Distribution – Detail* worksheet identifies certain keys that are used to determine if a pit is required and how the pit should be sized. The calculations that determine the actual number and size of the pits required are found in the *Distribution – Collapsed* worksheet. The *Distribution – Summary* worksheet contains formulas that aggregate, at the exchange level, the quantities and sizes of pits calculated in the *Distribution – Collapsed* worksheet. To create a reasonable flow to this document, all the calculations for identifying the number of pits required will be combined into a single subsection in this document.

19.	The remainder of this section explains in detail how each of the above components of the distribution network is calculated. The relevant subsection for each component is shown in brackets in the list above. For ease of understanding, when referencing an input value red text is used for the name assigned to that input value. Green text is used when referencing base data in the model and when referencing a calculated value blue text is used. Where one calculated value is dependent on other calculated values, a hyperlink to the other calculated values is included. To go to the page within this document on which the other calculated values are explained, click on the name of the calculated value.

20.	An index for the Engineering Distribution Module is provided in Attachment 1. This index provides cross-references between the model documentation and the Excel model for all input values, base data and calculated values. The index provides the name of the worksheet and the column or cell reference within the worksheet where each value can be found in the model. The index also identifies the paragraph number within this document where the explanation of each calculated value is provided.

Figure 2: Distribution Network Architecture

▬▬▬ - 100mm Conduit	⊗ - Pillar	⌂ - Single Dwelling Reidential Property
▬▬▬ - Pit Extensions	(P5) - No.5 Pit	▦ - Multi Dwelling Residents and Commercial Properties
▬▬▬ - 2 Pair Lead-ins		
▬▬▬ - Building Terminal Lead-ins	(P6) - No.6 Pit	

B.2   Length of Distribution Cable by Cable Size

21.   Efficient engineering best practice is to deploy 100 pair copper cables throughout the entire distribution network[5]. This engineering practice is referred to as a "non-tapered" distribution network design. Under this design rule, 100 pair cables are used for every distribution route from the customer premise to the pillar. If a copper cable on a particular route reaches its maximum capacity and an additional cable is required to serve the residual demand then an additional 100 pair cable will be installed.

22.   The alternative is the "tapered' design rule under which a range of copper cable sizes are used in the distribution network depending on the level of demand. The initial

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[5]   See Section 3.2 of Dimensioning Rules Document. Note that all copper cable in the distribution network is 0.40mm gauge cable (see Section 3.1.1 of Dimensioning Rules Document).

segment of cable closest to the customer premise will be sized using a 10, 30, 50 or 100 pair cable, depending on the demand at that segment. Larger sized cables will be used as cumulative demand on the route increases. Cumulative demand increases as additional customer premises are passed on the path back to the pillar. If demand on the route exceeds the maximum capacity of a 100 pair cable, an additional cable will be installed. However, unlike the non-tapered case, the additional cable will be sized using a 10, 30, 50 or 100 pair cable, depending on the demand at that segment and will increase in size as demand dictates, as the cable works its way back to the central office[6].

23. While efficient engineering best practice is the non-tapered design rule, the model can be run with a tapered option. To accommodate the tapered design rule in the model it is necessary to distinguish between:

- the number of cables at full cable capacity, which always refers to 100 pair cables (i.e. for both the tapered and non-tapered design options); and

- the length of cables at less than full cable capacity, which are provisioned with 100 pair cable when the non-tapered design rule is chosen and various cable sizes when the tapered design rule is chosen.

24. Disaggregating the calculation in this manner allows the model to build the network using either a non-tapered or tapered design.

25. The first step in calculating the length of distribution cable is to determine the number of fully utilised 100 pair cables. A cable is considered fully utilised when the actual demand being served divided by the design capacity (i.e. fill factor) is equal to the size of the cable. If the design capacity is 60 percent, a 100 pair cable would be fully utilised if it were serving 60 customers. In this instance, any demand increment in excess of 60 customers on any cable segment would require the use of an additional 100 pair cable (i.e. the largest cable used in the distribution network). The model determines the number of fully utilised 100 pair cables by segment. The total length of fully utilised distribution cable is then derived by multiplying the total length of each segment by the number of fully utilised cables serving that segment.

26. The next step in the process is to determine the length of the cables required to serve the remaining capacity requirement on every route segment (i.e. demand not served by fully utilised cables). The residual capacity requirement is determined by deducting the demand served by fully utilised cables from the total demand on the cable segment. This residual demand can then be served by the addition of a single 100 pair cable, in the case of a non-tapered network design, or smaller cables when the tapered network design is selected.

27. The total length of distribution cable is then calculated as the sum of the length of fully utilised cables and the length of cables required to serve remaining demand. These calculations are set out in more detail below.

B.2.1   Calculating the Total Length for Distribution Cables

28. The formula for determining the Total Length of Distribution Cables of 100 pairs is as follows: SUMIF(Size Cable to Serve Remaining Demand 100, Copper Cable Length)+SUMPRODUCT(Copper Cable Length, Fully Utilised 100 Pair Copper Cables). In this equation the length of 100 pair cables is calculated as the sum of the lengths for

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[6]   The term Central Office (CO) and Exchange are used interchangeably in this document and the Excel model.

100 pair copper cables serving the remaining demand and the number of fully utilised 100 pair copper cables multiplied by their associated cable length.

29. The formula for calculating the Total Length of Distribution Cables of 50, 30 and 10 pairs in the tapered network design is as follows: SUMIF(Size Cable to Serve Remaining Demand 50,30 or 10, Copper Cable Length). This formula simply sums the cable lengths for each size of cable other than the 100 pair cable.

B.2.2   Calculating the Length for Each Cable Segment

30. The formula for calculating Copper Cable Length is as follows: IF(Type of Structure= "LeadIn", 0, IF(OR(Lead-ins Served by Structure > 0, SUM(LeadIns Coming to Structure, Joined Pairs Cable Size Change, Joined Pairs Cable Route Mergers) > 0, 4.2, 0) + Segment Length)

31. This means that Copper Cable Length is usually equal to the Segment Length plus 4.2 metres. Segment Length is part of the model's base data and reflects the distance, in metres, between one structure, most often a pit, and the next. A length of 4.2 metres is added to the segment length to allow for a loop in the pit that can be pulled out in order to join cable together[7]. These joints occur at cable mergers (i.e. where cable routes merge or lead-ins are spliced to the distribution cable) or when the cable size is increased to meet greater demand in a tapered network architecture. There are two exceptions. First, when the Structure Type for the cable segment specifies "LeadIn" the Copper Cable Length is set to zero, reflecting the fact that the segment of cable is a lead-in and should not be counted in the length of distribution cable (as the length of cable used for lead-ins is calculated separately in the model). Second, when no cables are joined together at the structure, then the Copper Cable Length is equal to the Segment Length, as there is no need to add an additional 4.2 metres to allow for the joining of two or more cables.

32. The formula for calculating LeadIns Coming to Structure is SUMIF(Next Strucure Number, Current Structure Number, Structure Key) + SUMIF(Next Strucure Number, Current Structure Number, 2 Pair Lead-in Key). The structure key is 1 if the structure is a building terminal. This formula identifies all the pits that are serving 2 pair lead-ins or building terminal lead-ins. If cable segments ending at the current structure (i.e. has a next structure number that equals the current structure number for the pit) have been identified as either building terminal lead-ins or two pair lead-ins, the formula calculates the total number of the lead-ins entering the structure or pit.

33. The formula for calculating the 2 Pair Lead-in Key is as follows: IF(AND(Structure Type = 0, Building Terminal = "N", Trace Level <>1), 1, 0). The means that the 2 Pair Lead-in Key will only be equal to 1 if the type of structure is identified as a lead-in, it is not a building terminal and the structure is not the structure adjacent to the pillar.

34. The formula for calculating Structure Type is as follows: IF(Type of Structure = "LeadIn", 0, 1). This means if the type of structure is designated as a lead-in, then the Structure Type will be set to zero, otherwise it will be set to 1.

35. Structure Key is calculated as follows: IF(AND(Structure Type = 0, Building Terminal = "Y", Trace <> 1), 1, 0). This means that the Structure Key will only be equal to 1 if the type of structure is a lead-in and the property is a building terminal and the structure is not the pillar. If this is the case then the Segment Length is the lead-in.

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[7]   See Section 3.2.2 of Dimensioning Rules Document. While the Dimensioning Rules state a loop length of 6 metres should be included, 4.2 metres is used in the model to account for the provisioning of service joints in every second pit. (See Section 3.2 of Dimensioning Rules Document)

36.   The explanation of Joined Pairs Cable Size Change and Joined Pairs Cable Route Mergers are set out in Section B.3.

B.2.3   Calculating the Number of Fully Utilised 100 Pair Cables

37.   The formula for calculating the number of Fully Utilised 100 Pair Copper Cables is as follows: ROUNDDOWN(Cumulative Capacity Requirement Segment/ DistributionMaxCopperCableSize, 0).

38.   The number of fully utilised 100 pair copper cables is equal to the cumulative capacity demand at the segment divided by the maximum copper cable size (i.e. 100) for the distribution network. The result is rounded down to the nearest whole number, as any demand remaining after whole cables are full is accounted for separately. For example, if the cumulative demand for capacity for a particular segment is 365 pairs and the maximum copper cable size is 100 pairs then the number of fully utilised 100 pair copper cables is equal to the rounded down value of 365/100 or 3.

39.   The formula for the Cumulative Capacity Requirement Segment is as follows: SUMIF(Number to Identify Next Structure , DA# & Current Structure Number, Cumulative Capacity Requirement Segment) + Capacity Requirement at Structure.

40.   The purpose of this calculation is to determine the total capacity requirement at the structure point. This is accomplished by summing all the demand on distribution cable segments that feed into the structure and adding any demand (i.e. lead-ins) served directly from the structure. The formula first determines if the combination of the DA # and the Current Structure Number for the current row is equal to the combined Number to Identify Next Structure for any other rows of data. This allows the identification of all structures that are feeding into the current structure. Once these subordinate structures are identified the total of the demand from these structures is derived by summing the cumulative capacity requirement for each structure. This total is then combined with the capacity requirement for the current structure to arrive at the new cumulative capacity requirement for the segment.

41.   For example, assume that the letters in Figure 3 below represent structures. The first number in the brackets under the letter represents the capacity required at the structure and the second number in the brackets represents the cumulative capacity requirement at the structure. Structures F and G have no other previous structures that connect to them. Hence, the cumulative capacity requirements of the segments F and G are the same as the capacity required at F and G. Structure E has both F and G as previous structures that connect to it. Hence, the cumulative capacity requirement of segment E is the cumulative capacity requirement at F plus the cumulative capacity requirement at G plus the capacity required at E (5 + 2 + 3 = 10). Structure D has E as the only structure previously connected to it and hence the cumulative capacity required for segment D is equal to the cumulative capacity of segment E plus the required capacity at D (10 + 2 = 12). Structure B has both D and C as structures previously connected to it and hence the cumulative capacity at B is equal to the cumulative capacity of segment D plus the cumulative capacity of segment C plus the capacity required at B (12+ 10 +6 = 28). Finally, the structure A has only structure B connected to it and requires no capacity of its own. Hence, the cumulative capacity at A is equal to the cumulative capacity at B or 28.

Figure 3: Cumulative capacity requirement example

F   G
(5,5)   (2,2)
      E
      (3,10)
      D
      (2,12)
            C
      B   (2,10)
      (6,28)
      A
      (0,28)
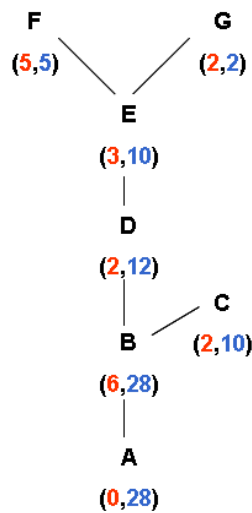
42.   Number to Identify Next Structure is simply calculated as DA# & Next Structure Number.

43.   The formula for Capacity Requirement at Structure is as follows: IF(Building Terminal = "Y", Building Terminal Size, Lead-ins Served by Structure / DistributionCopperCableFill). This means that if the structure is serving a building terminal then the capacity requirement at the structure is considered equal to the existing Building Terminal Size (measured in terms of number of copper pair cables required). If 2 pair lead-ins are being served by the structure then the capacity requirement at the structure is given by the number of lead-ins served by the structure divided by the fill factor for distribution copper cable. Given that the fill factor represents the maximum optimal capacity for designing and building a network, the formula provides the total capacity required at the structure[8]. For example, the capacity requirement for a single residential property is 1 pair adjusted for the fill factor (1/60%=1.67 pairs). Therefore, every single residential property is provisioned with a 2 pair lead-in, although only one pair is connected to the distribution cable.

B.2.4   Calculating the Size of Distribution Cables to Serve Remaining Demand

44.   Size Cable to Serve Remaining Demand is calculated using the following formula: IF(Copper Cable Size Index # = 0, 0, INDEX(DistributionCopperCableSizeRange, Copper Cable Size Index #)). Each index number reflects a different size of cable. The formula uses the index number to identify the appropriate copper cable sizes from the total range of distribution copper cable sizes. If the Copper Cable Size Index # is zero the cable segment is a lead-in and no distribution cables are required to meet remaining demand.

45.   The formula for Copper Cable Size Index # is as follows: IF(OR(Type of Structure = "LeadIn", Remaining Capacity Requirement = 0), 0, IF(TaperSelection = 2, 1, MATCH(Remaining Capacity Requirement , DistributionCopperCableSizeRange, -1))). This formula calculates an index number which specifies the size of the cable required to serve the remaining demand. This formula sets the index value to zero (i.e. no cable required) if the segment is a lead-in not distribution cable. It also sets the index value

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[8]   See Section 3.2.3.1 and 3.2.4 of Dimensioning Rules Document

to zero if there is no remaining capacity requirement on the segment. If there is no demand there is no need for another cable. However, if both of these conditions are present then the formula sets the index at 1 if a non-tapered design has been selected. A cable index of 1 signifies the need for a 100 pair cable. If a tapered design has been selected, the formula looks up an array of copper cable sizes and identifies the position in the array of the smallest value that is greater or equal to the remaining capacity requirement. In other words, the formula looks up the index for the smallest cable size that is large enough to handle the remaining capacity requirement and returns the placement of that cable size in the array.

46. The formula for Remaining Capacity Requirement is as follows: Cumulative Capacity Requirement Segment– DistributionMaxCopperCableSize * Fully Utilised 100 Pair Copper Cables. This formula simply takes the total capacity of a segment and deducts from it the capacity requirement that is being satisfied by fully utilised 100 pair cables. This leaves the remaining capacity requirement or demand that needs to be met by a cable utilised at less than full capacity.

B.3 Number, Size and Type of Cable Joints

47. There are 4 types of joints in the Distribution Module:

- Joints at cable mergers (route mergers and service connections);

- Joints where cable size changes (tapered network);

- Joints past maximum distance limits; and

- Joints on pillars.

48. With the exception of joints on pillars, a joint enclosure is required to house the joint. For joints on pillars there is also a cost related to joining distribution and main cables to the pillar. In this instance, a joint enclosure is not required. Since the costs vary depending on whether a joint enclosure is required, pillar joints are separately identified.

49. The total Number of Cable Joints for Mergers, Cable Size Changes and Distance Limits for each size of cable is calculated as follows for 100, 50, 30 and 10 pair cables:

- SUMIF(Size of Cables, 100, Joined Pairs Service Mergers) / 100 + COUNTIF(Joined Pairs Cable Size Change, 100) + COUNTIF(Joined Pairs Cable Route Mergers, 100) + COUNTIF(Distance Joints Not Fully Utilised Cables, 100)

- SUMIF(Size of Cables, 50, Joined Pairs Service Mergers) / 50 + COUNTIF(Joined Pairs Cable Size Change, 50) + COUNTIF(Joined Pairs Cable Route Mergers, 50) + COUNTIF(Distance Joints Not Fully Utilised Cables, 50)

- SUMIF(Size of Cables, 30, Joined Pairs Service Mergers) / 30 + COUNTIF(Joined Pairs Cable Size Change, 30) + COUNTIF(Joined Pairs Cable Route Mergers, 30) + COUNTIF(Distance Joints Not Fully Utilised Cables, 30)

- SUMIF(Size of Cables, 10, Joined Pairs Service Mergers) / 10 + COUNTIF(Joined Pairs Cable Size Change, 10) + COUNTIF(Joined Pairs Cable Route Mergers, 10) + COUNTIF(Distance Joints Not Fully Utilised Cables, 10)

50. The formulas first sum the total number of pairs joined at service mergers (i.e. connecting customer services to the distribution network) for each size of cable and

then divide by the cable size to determine the number of cables that are being joined[9]. This amount is then added to the number of cables joined by size of cable at route mergers, changes in cable size (tapered network design only) and distance limits (not fully utilised cables).

51. The calculation of the number of 2 Pair Cable Joints is as follows: SUMIF(Size of Cables, 2, Joined Pairs Service Mergers). In other words, the number of 2 pair cable joints is equal to the number of 2 pair service connections. Note that there is no need to divide by cable size as is the case with the other sized cables. A 2 pair cable has only 1 joint so the number of joints does not have to be divided by 2 to get the number of cables. The number of joints is identical to the number of cables.

52. Total number of Fully Utilised Cables Requiring Distance Joints is the sum of all fully utilised distance joints calculated as follow SUM(Distance Joints Fully Utilised Cables).

B.3.1 Joints at Cable Route Mergers and Service Mergers

53. Joined Pairs Cable Route Mergers are differentiated by cable size only when the tapered network architecture is selected. The calculation for identifying these cable joints is: IF(Branches Coming From Dependent Pits > 1, Size Cable to Serve Remaining Demand, 0). If there is a merger at the structure (i.e. cables are coming into the structure from more than one other subordinate structure) the formula identifies the size of cable being merged.

54. Joined Pairs Service Mergers are differentiated by the size of the cables that are being joined, for example, whether a joint is for a 2 pair cable or a 100 pair cable. A service merger occurs when the facility providing a customer service (i.e. lead-in or building terminal) is joined to the distribution network. The formula used to calculate Joined Pairs Service Mergers is as follows: IF(Building Terminal = "Y", Size of Required Terminal + Fully Utilised 100 Pair Building Terminals * LeadinMaxSize, Lead-ins Served by Structure). This means that if the structure is connected to a building terminal then the number of joints is equal to the building terminal size (measured in terms of number of cable pairs) otherwise the number of joints is equal to the number of 2 pair lead-ins served by the structure.

55. Size of Cables is calculated using the formula INDEX(ServingPitCableRange, MATCH(IF(Building Terminal = "Y", IF(Fully Utilised 100 Pair Lead-ins > 0, MaxServing PitCable,Size Lead-in Cable to Serve Remaining Demand), Number of Pairs), ServingPitCableRange, -1)).

56. This formula chooses the appropriate Size of Cables. If the structure is connected to a building terminal and the number fully utilised 100 pair lead-ins is above zero then the size of the cable joint is equal to the maximum serving pit cable size (ie 100 pair cable). If the structure is connected to a building terminal and there are no fully utilised 100 pair lead-ins then the size of the cable is equal to the cable size required to serve remaining demand. If the structure is not connected to a building terminal then the size of the cable joint is equal to the number of pairs.

B.3.2 Joints at Cable Size Changes

57. If the tapered network architecture option is selected, cables will need to be joined at every point at which the size of cable required to serve the demand changes. The

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[9]   Note that the Cost Calculation Module determines the total joint cost by multiplying each cable by the number of pairs in the cable times the cost per pair.

formula for calculating Joined Pairs Cable Size Change (which identifies and calculates the size of these joints) is as follows: IF(AND(TaperSelection = 1, Branches Coming From Dependent Pits = 1, SUMIF(Number to Identify Next Structure, DA# & Structure Number, Size Cable to Serve Remaining Demand) > 0, SUMIF(Number to Identify Next Structure, DA# & Structure Number, Size Cable to Serve Remaining Demand) <> Size Cable to Serve Remaining Demand), Size Cable to Serve Remaining Demand).

58. In a tapered architecture the above equation sets the size of the joint equal to the size of the cable being joined. However, this type of joint is only required if all the following conditions are met:

- There is only one cable coming into the structure from subordinate structures (i.e. the structure is not at a cable merger);

- There are some distribution (not lead-ins) cables coming into the structure from a subordinate structure (i.e. there is 1 or more cables coming from a structure with a next structure identifier that is the same as the current structure identifier for the structure being analysed); and

- The size of the cable coming from that subordinate structure is different to the size of cable leaving the current structure (i.e. a joint is required to connect the two sizes of cable).

59. If any of these conditions do not exist, no cable size joint are required.

B.3.3 Joints Past Maximum Distance Limits

60. A distance joint is required if the distance between joints exceeds the maximum haul length for the size of cable being placed. The model calculates distance joints separately for fully utilised large cables and those cables used to serve any remaining demand. The distance between joints for fully utilised cables frequently varies significantly from the distance between joints for cables that are not fully utilised. At cable mergers, demand is combined for those cables that have some additional capacity available. This combination requires a joint. Therefore, the length between cable joints is reset to 0 at the cable mergers for cables operating at less than full capacity. Once the largest size cable is fully utilised there will be no need for additional mergers or cable sizing joints. The cable is simply dead headed back to the central office. Therefore, the likelihood of a fully utilised cable exceeding its distance limitations is significantly greater than other cables and is therefore addressed separately.

61. Distance Joints Fully Utilised Cables is calculated as follows: (Fully Utilised 100 Pair Copper Cables – SUMIF(Number to Identify Next Structure, DA# & Current Structure Number, Fully Utilised 100 Pair Copper Cables) * ROUNDDOWN(Total Distance to Pillar / IF(TaperSelection = 2, NonTaperMaxCopperCableLength, DistributionMaxCopperLengthCable), 0). In this equation the model identifies any fully utilised cables that become fully utilised at the current structure (i.e. there is a fully utilised cable in the current segment that did not exist on the prior segment). Once these cable have been identified, the number of distance joints required for these cables is calculated as the total distance to the central office divided by the maximum haul length for large distribution cables, rounded down to the nearest whole number.

62. Distance Joints Not Fully Utilised Cables needs to account for joints at cable route mergers that may already exist on the route. The formula for identifying these joints is: IF(OR(Cumulative Capacity Requirement Segment= 0, Copper Cable Length= 0), 0, ROUNDDOWN(Cumulative Distance From Last Joint/ IF(TaperSelection = 2, NonTaperedMaxCopperCableLength, INDEX(DistributionCopperCableLengthRange,

Copper Cable Size Index #)), 0)). If there is no demand on the segment or the segment is a lead-in (i.e. distribution copper length is 0) no distance joints are required. Otherwise, the number of distance joints required is calculated as the total distance from last joint divided by the maximum haul length for 100 pair cables in a non-tapered network or the maximum haul length for the size of cable being used in the tapered network.

63.   The distance from the last cable route merger, distance joint or cable size change is required in order to determine if a distance joint is required. The Cumulative Distance From Last Joint calculation identifies this distance using the following formula: IF(AND(Joined Pairs Cable Size Change = 0, Joined Pairs Cable Route Mergers= 0, Copper Cable Length > 0, Cumulative Capacity Requirement Segment > 0), Copper Cable Length + SUMIF(Number to Identify Next Structure,DA# & Current Structure Number, Cumulative Distance From Last Joint) - SUMIF(Number to Identify Next Structure, DA# & Current Structure Number, Distance Joints Not Fully Utilised Cables)) * IF(TaperSelection = 2, NonTaperedMaxCopperCableLength, INDEX(DistributionCopperCableLengthRange, Copper Cable Size Index #)), 0)). If there are no changes in cable size or route merger joints on the segment and a cable is required to serve remaining demand, then the cumulative distance from the last joint needs to be identified to see if a distance joint is required. This distance is calculated by adding the segment length for the current structure to the cumulative distance from the last joint for the structure that feeds the current structure and deducting the total number of distance joints that would be needed in the current section multiplied the maximum haul length for the type of cable in the segment.

B.3.4   Joints on Pillars

64.   The formula for calculating Number of Cable Joints on Pillar is as follows: Number of Large Terminal Strips * 2 + Number of Small Terminal Strips. This calculation sets the number of 100 pair cable joints on pillars equal to two times the total number of large terminal strips (large terminal strips accommodate 200 pairs each) plus the number of small terminal strips (small terminal strips accommodate 100 pairs each). Every pair within a distribution cable is joined on the pillar. Similarly, main cables attach to pillars in multiples of 100, and thus the number of 100 pair joints is equal to the number of pillar strips attaching them to the pillar.

B.4   Number of Pillars

65.   There are two pillar sizes included in the Distribution Module and the size and number of pillars required is dependent on the level of demand at the pillar locations. Large, 1800 pillars can accommodate a maximum of 1000 pairs on the distribution side and 600 pairs on the main side[10]. Small, 900 pair, pillars can accommodate a maximum of 500 pairs on the distribution side and 300 pairs on the main side[11].

B.4.1   Large Pillars

66.   The number of Large Pillars is calculated as SUM(Fully Utilised 1800 Pillars) + COUNTIF(Type of Pillar Required, 1). This means that the number of large pillars required is the sum of the number of fully utilised 1800 pillars and the number of pillars required to serve remaining capacity when that type of pillar used is a large pillar (i.e. identified by a 1).

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[10]   See Section 3.3.1 of Dimensioning Rules Document
[11]   See Section 3.3.1 of Dimensioning Rules Document

67. Fully Utilised 1800 Pillars is calculated as follows: IF(OR(Number of Distribution Cables Connected to Pillar * 100 > MaxPillarCapacity, Pairs Terminated Main Side Pillar > MaxPillarSize), MAX(ROUNDDOWN(Number of Distribution Cables Connected to Pillar * 100/MaxPillarCapacity, 0), ROUNDDOWN(Pairs Terminated Main Side Pillar / MaxPillarSize, 0)), 0). This formula checks if either the number of cable pairs attached to the distribution or main side of the pillar exceeds the design capacity for an 1800 Pillar. If it does, then the number of 1800 pillars at capacity is calculated by dividing the number of pairs terminated on either the distribution or main side of the pillar by the maximum number of pairs that can be accommodated on the distribution or main side of the pillar. The larger of these amounts rounded down to the nearest whole number, gives the total number of fully utilised pillars required for each distribution area. If the cables terminating on either side of the pillar do not exceed the design capacity for 1800 pair pillars then this formula returns a value of zero.

68. Type of Pillar Required is calculated as follows: IF(OR(Main Remaining Capacity Requirement > MinPillarSize, Distribution Remaining Capacity Requirement > MinPillarCapacity), 1, 2). This formula checks if the remaining demand, demand not served by 1800 pillars at full utilisation, on either the distribution or main side of the pillar exceeds the respective capacity limitations for a small pillar (900 pillars). If these capacity limitations are exceeded then the type of pillar required is identified as a large pillar (i.e. type of pillar required = 1), otherwise a small pillar is identified (i.e. type of pillar required = 2).

69. Pairs Terminated Main Side Pillar is calculated as follows: ROUNDUP(Demand Served by Pillar / FeederFill /100, 0) * 100. The number of pairs terminated on the main side of the pillar is equal to the demand served by the pillar divided by the feeder fill factor. The feeder fill is divided by 100 to ensure that the roundup function rounds the number of pairs up to the nearest 100, as the minimum cable size on the feeder side of the pillar is 100 pair cable.

70. Main Remaining Capacity Requirement is calculated as follows: MAX(0, Pairs Terminated Main Side Pillar – (Fully Utilised 1800 Pillars * MaxPillarSize)). The remaining demand or capacity requirement on the main side of the pillar is calculated as the total number of pairs terminated on the main side of the pillar less the number of pairs that are terminated on fully utilised large pillars. If this figure is less than zero then the remaining capacity requirement is set to zero.

71. Distribution Remaining Capacity Requirement is calculated as follows: MAX(0, (Number of Distribution Cables Connected to Pillar * 100) – (Fully Utilised 1800 Pillars * MaxPillarCapacity)). The remaining demand or capacity requirement on the distribution side of the pillar is calculated as the total number of pairs connected to the distribution side of the pillar less the number of pairs that are connected to fully utilised large pillars. If this figure is less than zero then the remaining capacity requirement is set to zero.

72. The Number of Distribution Cables Connected to Pillar is calculated as follows: SUMIF(Pillar Key, DA# & "END", Number of Cables in Segment). This calculation identifies the number of distribution cables connected to the pillar for each DA. The pillar key identifies the segment of distribution cables that are attached to the pillar. Summing the number of cables in these segments identifies the total number of distribution cables connected to a pillar within the DA.

73. Pillar Key is calculated as IF(Trace Level = 1, DA# & "END", DA#). This sets the Pillar Key equal to the DA number plus the word "END" when the trace level is equal to 1. Trace level counts the number of cable segments in a route, starting at the pillar. If trace level is equal to one, the cable segment is attached to the pillar. When the trace level is not set at one, the Pillar Key is set equal to the DA number only.

74. Number of Cables in Segment is calculated as follows: Fully Utilised 100 Pair Copper Cables + IF(Remaining Capacity Requirement > 0, 1, 0). This means that the number of cables in a segment is equal to the number of fully utilised cables plus 1 cable used at less than full capacity to accommodate any remaining demand, if any remaining demand exists.

B.4.2   Small pillars

75. The number of Small Pillars is calculated as COUNTIF(Type of Pillar Required, 2). This means that the number of small pillars required is equal to the number of pillars required to serve remaining capacity when that type of pillar required is identified as a small pillar (ie. Identified by a 2).

B.5   Pillar Terminal Strips

76. There are two sizes of pillar terminal strips included in the model: large and small. A large terminal strip is used with large (1800) pillars and can accommodate 200 cable pairs. A small terminal strip is used in conjunction with small (900) pillars and can accommodate 100 cable pairs. The formula used to calculate the Number of Large Terminal Strips is SUMIF(Type of Pillar Required, 1, Terminal Strips Needed) and for the Number of Small Terminal Strips is SUMIF(Type of Pillar Required, 2, Terminal Strips Needed). Hence, this formula simply sums up the number of terminal strips needed by terminal strip type.

77. Terminal Strips Needed is calculated as follows: IF(Type of Pillar Required = 0, 0, ROUNDUP(Number of Distribution Cables Connected to Pillar * 100 + Pairs Terminated Main Side Pillar) / INDEX(TerminalStripSizingRange, Type of Pillar Required), 0)). This sums the number of pairs on both the distribution and feeder side of the pillar and divides by the number of pairs that can be accommodated on the terminal strip. The number of pairs that can be accommodated on the terminal strip is dependent on the type of pillar that is required – either large (i.e. 200 pairs) or small (i.e. 100 pairs).

B.6   Length of Distribution Conduit

78. The total length of distribution conduit is the sum of the conduit lengths required for pit extensions and the length of conduit that accommodates cables running alongside roads.

B.6.1   Length of Distribution Conduit - Pit Extensions

79. The total number of Pit Extensions is the sum of all pit extensions required across all DAs, that is, SUM(Pit Extensions Required).

80. Pit Extensions Required is calculated as ROUNDUP(Non Commercial Addresses / WeightedLeadInsPerPit, 0) + SUMIF(DA#, aggregated DA#, Building Terminal Key) / 2. Therefore, the number of pit extensions required for non-commercial addresses in each DA is equal to the number of pits that would be required to serve all non-commercial addresses (i.e. addresses not served by a building terminal), based on an assumption that each pit serves customers on each side of the road. Dividing the total number of non-commercial addresses by the assumed number of customers served by each pit (WeightedPairsPerPit), identies the number of pits required to serve this customer group. For building terminals, the number of pit extensions required is equal to the number of pits serving building terminals divided by 2. The division by 2 reflects the fact that, on average, half of the buildings are on the opposite side of the street and hence a pit extension is required to connect these customers. The sum of these two amounts identifies the total number of pit extensions required in each DA.

81. Non Commercial Addresses is calculated as SUMIF(DA#, aggregated DA#, Lead-ins Served by Structure). This formula sums the number of lead-ins served by a structure up to the DA level.

82. Building Terminal Key is calculated as IF(OR(Fully Utilised 100 Pair Building Terminals > 0, Remaining Terminal Demand > 0), 1, 0). This formula identifies every location served by one or more building terminals by checking if there are any cable pairs connected to a building terminal. If there is then the building terminal key is set to 1.

B.6.2 Length of Distribution Conduit – Cable Runs Along Roads

83. The standard distribution conduit is 100mm. It is permissible to use up to 50 metres of 50mm conduit at the very end of a cable route (i.e. to reach the last joint) when a single 100 pair distribution cable is all that is required to serve demand on the last cable segment. Therefore, there are two sizes of conduit included in the model, 100mm and 50mm[12].

84. In addition to conduit size, conduit runs are also differentiated by the customer density within the distribution area being served. The purpose of disaggregating conduit runs by density range is to better assign costs to the conduit trenching and placement functions. In dense urban areas, the number of roads, driveways, sidewalks and other manmade obstacles significantly exceed those found in similar sized rural areas. These obstacles increase the cost of placing the conduit runs. To allow the model to account for these cost differences between areas with differing density characteristics, all the conduit runs and pits in the model are assigned to one of five density ranges. This assignment is done at the DA level and is based on the service density within the DAs.

85. The conduit runs are also separately identified by the number of conduits in a run since costs vary by size of conduit configuration. Therefore, the physical length of distribution conduit needs to be broken down by both a density index and the size of the conduit configuration. There are 5 density options and 6 conduit configurations included in the model. Note that the model allows for a sixth density range in case it is required in the future. As a result, the physical length of distribution conduit is broken down into 30 categories.

86. In each case, the formula for calculating the physical length of the distribution conduit is the same:

- SUMIF(Density Index, x, 8 100mm Conduit Runs)

- SUMIF(Density Index, x, 6 100mm Conduit Runs)

- SUMIF(Density Index, x, 4 100mm Conduit Runs)

- SUMIF(Density Index, x, 2 100mm Conduit Runs)

- SUMIF(Density Index, x, 1 100mm Conduit Runs)

- SUMIF(Density Index, x, 1 50mm Conduit Runs)

87. Where x takes the value of 1 to 5, indicating one of the 5 density options in use.

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[12]   See Section 3.2.1.1 of Dimensioning Rules Document.

88. Therefore, the length of conduit for each category is calculated as the sum of the length of conduit included under each conduit configuration for each density index.

89. Density Index is calculated as: MATCH(Density, DensityRange, -1). This formula finds the smallest value in the DensityRange that is greater than or equal to Density (i.e. the calculated density of the DA) and assigns the value for that range. The DensityRange has 6 possible values and hence this formula returns a value of between 1 and 6[13].

90. Density is calculated as Demand Served by Pillar / Area (sq. km). This formula calculates the service density for the DA in terms of SIOs per square kilometre.

91. 8 100mm Conduit Runs is calculated as SUMIF(Conduit Configuration Key, DA#&"-1", Segment Length. This sums the segment lengths for all conduit runs between structures with the same DA number where the configuration key is equal to the DA number and "-1", where "-1" indicates that 8 100 mm conduit runs are required.

92. 6 100mm Conduit Runs is calculated as SUMIF(Conduit Configuration Key, DA#&"-2", Segment Length. This is exactly the same as for 8 100mm Conduit Runs except -2 indicates that 6 100mm conduit runs are required.

93. 4 100mm Conduit Runs is calculated as SUMIF(Conduit Configuration Key, DA#&"-3", Segment Length. This is exactly the same as for 8 100mm Conduit Runs except -3 indicates that 4 100mm conduit runs are required.

94. 2 100mm Conduit Runs is calculated as SUMIF(Conduit Configuration Key, DA#&"-4", Segment Length. This is exactly the same as for 8 100mm Conduit Runs except -4 indicates that 2 100mm conduit runs are required.

95. 1 100mm Conduit Runs is calculated as SUMIF(Conduit Configuration Key, DA#&"-5", Segment Length. This is exactly the same as for 8 100mm Conduit Runs except -5 indicates that 1 100mm conduit run is required.

96. 1 50mm Conduit Runs is calculated as SUMIF(Conduit Configuration Key, DA#&"-6", Segment Length. This is exactly the same as for 8 100mm Conduit Runs except -6 indicates that 1 50mm conduit run is required.

97. Conduit Configuration Key is calculated as DA# & "-" & IF(Size of Conduit Required > 0, INDEX(ConduitConfigurationRange, MATCH(Size of Conduit Required, ConduitConfigurationSizeRange, -1)), 0). This formula sets the conduit configuration key equal to the DA# with a "-" and the appropriate conduit configuration number. The MATCH formula looks up the conduit configuration size range, which ranges from 0.5 to 8, and returns the position in the range of the smallest value that is greater or equal to the size of the conduit required. For example, if the size of the conduit required is 1 then the MATCH formula looks up the ConduitConfigurationSizeRange and given that there is a value in the range exactly equal to 1 (ie 1 100mm Conduit Run), returns the position of this value in the range. The position of 1 in the range is 5. The formula then returns the value of the item in position 5 of ConduitConfigurationRange, which in this case is the number 5. Therefore, if the DA# was P1, then the Conduit Configuration Key would be set to P1-5. This index number allows the model to aggregate conduit lengths by the size of the conduit run.

98. Size of Conduit Required is calculated as IF(AND(Branches Coming From Dependent Pits = 0, Segment Length < 50), 0.5, ROUNDUP(Number of Cables in Segment/4, 0))) *

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[13] Note that only five density ranges are currently used for Band 2.

Structure Type The size of conduit required is calculated as the number of cables in the segment divided by 4 rounded up to the nearest whole number. The total is divided by four because a conduit can accommodate a maximum of 4 100 pair cables[14]. The only exception to this calculation is for short segments at the very end of a conduit runs. If the segment is at the end of a conduit run (i.e. does not have cables coming in from dependent pits) and the segment length is less than 50 metres long a 50mm conduit would be used to serve the section[15].

99.   Branches Coming From Dependent Pits is calculated as SUMIF(Next Structure Number, Current Structure Number, Structure Type). Therefore, if the current structure number is the next structure number for any other structures in the DA (ie if the current structure has any dependent structures) then this formula sums the cable types for those structures. Given the cable type is equal to 1 whenever the structure is not a lead-in this formula adds the number of branches (ie cable segments that are not lead-ins) that are dependent on each structure.

B.7   Number of Pits

100.   The cost of pits in the model is differentiated by density (as an indicator of topology) and pit type. As discussed above, there are 5 density options included in the model and three types of pits – number 9 pits, number 6 pits and number 5 pits[16]. Therefore, the number of pits is divided into 15 categories. Number 9 and number 6 pits are used where routes merge or where segments of cable exceed the maximum distance between pits[17]. There is also one Number 9 pit at every pillar. Number 5 pits are used in all other cases[18].

101.   In each case, the formula for calculating the number of pits is the same:

- SUMIF(Density Index, x, Number of No. 9 Pits Required)

- SUMIF(Density Index, x, Number of No. 6 Pits Required)

- SUMIF(Density Index, x, Number of No. 5 Pits Required)

102.   Where x takes the value of 1 to 5, indicating one of the 5 density options in use in Band 2.

103.   Therefore, the number of pits for each category is calculated as the sum of the number of pits by type and density index.

104.   Number of No. 9 Pits Required is calculated as follows: SUMIF(Pit Sizing Key, DA#&2, Pits at Route Mergers and Distance Limits) + 1. This formula sums the number of pits required at route mergers and distance limits across all structures with the same DA number where the Pit Key is set equal to the DA#&2. The "2" indicates that a number 9 pit is required. An additional No. 9 Pit is added to every DA because a No. 9 pit is required where the distribution cables connect to the pillar[19].

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[14]   See Section 3.2.1.1 of Dimensioning Rules Document
[15]   See Section 3.2.1.1 of Dimensioning Rules Document
[16]   See Section 3.2.2 of Dimensioning Rules Document
[17]   See Section 3.2.2 of Dimensioning Rules Document
[18]   See Section 3.2.2 of Dimensioning Rules Document
[19]   See Section 3.2.2 and 3.3.1 of Dimensioning Rule Document

105. Number of No. 6 Pits Required is calculated as follows: SUMIF(Pit Sizing Key, DA#&1, Pits at Route Mergers and Distance Limits). This formula sums the number of pits required at route mergers and distance limits across all structures with the same DA number where the Pit Key is set equal to the DA#&1. The "1" indicates that a number 6 pit is required.

106. Number of No. 5 Pits Required is calculated as follows: ROUNDUP(Non Commercial Addresses - Lead-ins Served by #9 and #6 Pits) / WeightedLeadInsPerPit, 0) + Building Terminals Not Served by #9 and #6 Pits + ROUNDUP(SUMIF(DA#, DA#, Building Terminal Key) / 2, 0) + ROUNDUP(0.25 * Non Commercial Addresses / WeightedLeadInsPerPit, 0). The number of number 5 pits required is determined by the number of lead-ins and building terminals that are not served by number 6 and number 9 pits. For non-commercial addresses this is calculated by deducting the number of lead-ins that are served by number 9 and 6 pits from the total number of non-commercial addresses and dividing by the average number of lead-ins per pit. For building terminals this is determined by the number of building terminals that are not served by number 9 or 6 pits plus half the the total number of building terminals. The model assumes that half the building terminals will be located on the opposite side of the street from the distribution conduit run. In these instances a pit will need to be placed on each side of the street In addition, 25 percent of the time a pit will be required on both sides of the street when serving 2 pair lead-ins.

107. Pit Sizing Key is calculated as IF(Pits at Route Mergers and Distance Limits > 0, IF(Branches Coming From Dependent Pits > 2, DA#&2, DA#&1), 0). This formula identifies whether a pit is required due to either distance limits or route mergers. If a pit is required the size of the pit required is determined by the number of conduits entering on either side of the pit. A number 6 pit can only allow for 2 conduits per end. Therefore, if the number of conduits entering the pit exceeds 2 the Pit Key is set equal to the DA# and number 2 (number 9 pit required). Otherwise the Pit Key is equal to the DA# and number 1 (number 6 pit required). If no pits are required at route mergers or distance limits then the Pit Key is set to zero.

108. Pits at Route Mergers and Distance Limits is calculated as IF(AND(Structure Type > 0, Branches Coming From Dependent Pits > 1), 1 + ROUNDDOWN(Segment Length / INDEX(PitSpacingRange, 3), 0), 0). Route mergers are identified where the segment is not a lead-in and there is more than one branch coming from dependent pits. At this point a pit is required to merge the multiple routes. The number of pits at distance limits is calculated as the segment length divided by the maximum distance between pits[20]. In other words, a pit will be put in place whenever the maximum allowable distance between pits is exceeded.

109. Lead-ins Served by #9 and #6 Pits is calculated as SUMIF(DA# disaggregated, DA# aggregated, Lead-ins Served by Pits at Route Mergers). This formula aggregates the number of lead-ins served by number 9 and number 6 pits at the DA level.

110. Building Terminals Not Served by #9 and #6 Pits is calculated as SUMIF(DA# disaggregated, DA# aggregated, Building Terminal Key) – SUMIF(DA# disaggregated, DA# aggregated, Building Terminals served by Pits at Route Mergers). The number of building terminals not served by number 9 or number 6 pits is calculated as the total number of building terminals summed across all structures to the DA level less the number of building terminals that are served by pits at route mergers.

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[20]   See Section 3.2.2.1 of Dimensioning Rules Document

111. Lead-ins Served by Pits at Route Mergers is calculated as IF(Pits at Route Mergers and Distance Limits > 0, Lead-ins Served by Structure, 0). If there are any pits required at route mergers or distance limits then the number of lead-ins served by pits at route mergers is equal to the number of lead-ins served by the structure where the merger occurs. Otherwise it is equal to zero.

112. Building Terminals served by Pits at Route Mergers is calculated as IF(Pits at Route Mergers and Distance Limits > 0, Building Terminal Key - Structure Key, 0). If there are any pits required at route mergers or distance limits then the building terminals served by pits at route mergers will be equal to 1 only if there are pairs connected to a building terminal and the structure is not a lead-in. Otherwise, building terminals served by pits at route mergers will be set equal to zero.

B.8   Number of Building Terminals

113. It should be noted that the building owner is responsible for installing the building terminal frame and placing the entrance facility. Telstra is responsible for attaching a terminal strip to the building terminal and running the cables to attach the terminal strips to the network.

114. The number of building terminals required is calculated by the size of the building terminal in terms of number of pairs (100 pair, 50 pair, 30 pair and 10 pair). The calculation of buiding terminals required is a two step process. The calculation determines how many multiples of fully utilised one hundred pair cables are going to be required to serve the demand at the location. Once this is accomplished, the model determines what size terminal strips and connecting cables will be required to serve the remaining demand (i.e. the demand not being met by fully utilised large terminal strips).

B.8.1   100 pair building terminals

115. The number of 100 Pair Building Terminals is calculated as SUM(Fully Utilised 100 Pair Building Terminals) + COUNTIF(Size of Required Terminal, 100). This calculates the number of 100 pair building terminals required as the sum of the number of fully utilised 100 pair building terminals plus the number of building terminals required to meet remaining demand where the size of the required terminal is 100 pairs.

116. Fully Utilised 100 Pair Building Terminals is calculated as IF(Building Terminal = "Y", ROUNDDOWN(Capacity Requirement at Structure / LeadInMaxSize, 0, 0). This means that if the structure is serving a building terminal, the number of fully utilised 100 pair building terminals is equal to the number of pairs required at the structure divided by the maximum lead-in size (ie 100 pairs). For example, if the capacity requirement at the structure was 220 pairs then the number of fully utilised 100 pair building terminals would be equal to 2, that is, the rounded down result of 220/100. Therefore, 200 pairs of the total 220 requirement will be satisfied by the use of 2 fully utilised 100 pair building terminals and the additional 20 pairs will be accommodated by a smaller building terminal (see below).

117. Size of Required Terminal is calculated as follows: IF(Remaining Terminal Demand > 0, INDEX(LeadInSizeRange, MATCH(Remaining Terminal Demand, LeadInSizeRange, -1)), 0). If any demand remains after accounting for the demand served by fully utilised 100 pair building terminals then the size of the terminal required for that remaining demand is selected as the smallest terminal size that is greater or equal to the remaining terminal demand. For instance, in the example cited in the previous

paragraph, there was a remaining demand of 20. The cables sizes available to serve building terminals are 100, 50, 30 and 10 pairs[21]. Therefore a building terminal size of 30 pairs would have been chosen.

118. Remaining Terminal Demand is calculated as: IF(Building Terminal = "Y", Capacity Requirement at Structure - Fully Utilised 100 Pair Building Terminals * LeadInMaxSize, 0). This calculates remaining terminal demand, in terms of cable pairs, as the difference between the total number of pairs required at the structure and the number of pairs that are connected to fully utilised 100 pair building terminals.

B.8.2   50, 30 and 10 Pair Building Terminals

119. The number of 50, 30 and 10 Pair Building Terminals is calculated as: COUNTIF(Size of Required Terminal, x pairs), where x is 50, 30 or 10. This simply sums the number of terminals required to meet remaining demand where the required size of the terminal is 50, 30 or 10 pairs.

B.9   Length of Building Terminal Lead-ins

120. The length of cables serving building terminals is differentiated by cable size, 100 pair, 50 pair, 30 pair and 10 pair.

121. The total Length of 100 Pair Building Terminal Lead-ins is calculated as: SUMIF(Size Lead-in Cable to Serve Remaining Demand , 100, Length of Building Terminal Lead-ins) + SUMPRODUCT(Fully Utilised 100 Pair Lead-ins * Length of Building Terminal Lead-ins). The length of 100 pair building terminal lead-ins is therefore equal to the sum of the building terminal lead-in cable lengths, where the size of the cable to service remaining demand is 100 pairs plus the length of all fully utilised 100 pair building terminal lead-ins.

122. The Length of 50, 30 and 10 Pair Building Terminal Lead-ins is calculated as SUMIF(Size Lead-in Cable to Serve Remaining Demand , x, Length of Building Terminal Lead-ins), where x is 50, 30 or 10. This sums the length of cables to serve remaining demand when the size of that cable is equal to 50, 30 or 10 pairs.

123. Fully Utilised 100 Pair Lead-ins is set equal to the number of Fully Utilised 100 Pair Building Terminals since both serve the same demand and come in identical sizes.

124. Size Lead-in Cable to Serve Remaining Demand is set equal to the Size of Required Terminal to which the cable will be attached.

125. Length of Building Terminal Lead-ins is calculated using the following formula: IF(Building Terminal = "Y", IF(Structure Key = 1, Segment Length, AverageLargeLeadInLength),0). This means that if a structure is serving a building terminal and the structure is a lead-in then the length of the lead-in is equal to the Segment Length. Otherwise, it is equal to the AverageLargeLeadInLength. The AverageLargeLeadInLength is the average length for all building terminal lead-ins in the exchange for which there is data.

B.10   Number and Length of 2 Pair Lead-ins

126. The model calculates both the number of 2 pair lead-ins and the length of cable for 2 pair lead-ins where the structure in the base data is identified as a lead-in.

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[21]   See Section 3.2.3.2 Dimensioning Rules Document

B.10.1   Number of 2 Pair Lead-ins

127.   The total Count of 2 Pair Lead-ins for the exchange is caculated as SUM(Number of 2 Pair Lead-ins). This calculation combines all the lead-in counts for each structure to get the total for the exchange.

128.   The Number of 2 Pair Lead-ins is calculated as follows: IF(Number of Pairs > 0, Lead-ins Served by Structure, 0). This formula sets the number of 2 pair lead-ins equal to the number of lead-ins served by each structure that is not a building terminal.

129.   Number of Pairs is calculated as follows: IF(Building Terminal = "N", MinLeadIn, 0). If the structure is not connected to a building terminal then the size of any lead-ins served by the structure would be a normal 2 pairs per site (i.e. MinLeadin)[22].

B.10.2   Length of Cable for 2 Pair Lead-ins

130.   The total Cable Length for 2 Pair Lead-ins is calculated using the following formula: SUMPRODUCT(Number of 2 Pair Lead-ins, Length of 2 Pair Lead-ins). This formula calculates the length for all the 2 pair lead-ins in the exchange to determine the two pair cable requirement for the exchange.

131.   The formula for calculating the Length of 2 Pair Lead-ins is as follows: IF(Lead-ins Served by Structure > 0, IF(Building Terminal = "N", IF(2 Pair Lead-in Key = 1, Segment Length, AverageSmallLeadinLength),0),0). This means that the length of the lead-in will be set at the segment length when the segment is designated as a lead-in (i.e. when the 2 Pair Lead-in Key is equal to 1). If the base data does not identify the actual length of the lead-in, then the length of the lead-in is set at the AverageSmallLeadinLength. The AverageSmallLeadinLength is the average length for all the lead-ins for which there is an actual lead-in length measurement (see below).

132.   The formula for calculating the AverageSmallLeadinLength is as follows: IF(SUM(2 Pair Lead-in Key =0,0,SUMIF(2 Pair Lead-in Key =1,Segment Length)/SUM(2 Pair Leadin Key). This means that AverageSmall LeadinLength is set at the average length for those lead-ins for which there is a specific length included in the base data. The base data only includes length data for a portion of all the lead-ins. This formula calculates the average length for the lead-ins for which there is data so that it can be used for lead-ins for which no data exists. Note that this calculation is located on the *Distribution – Inp*u*t*s worksheet.

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[22]   *See 3.2.3.2 of Dimensioning Rules Document*

C   Engineering Main Module

133.   The Engineering Main Module models the architecture of the Main network. This module uses efficient best engineering practice design rules together with base data extracted, translated and loaded from Telstra's Cable Plant Records to design an optimised copper main network for the supply of the ULLS. The distribution network architecture used in the model is illustrated in Figure 4 below.The Engineering Main Module also models fibre main cable. This is used primarily for calculating the cost of supplying basic access (ie it is used in the basic access version of the model). However, it is also necessary in the ULLS version of the model so that costs can be shared between copper and fibre fed services.

134.   The output of the Main Module is a list of the amount of labour, plant and equipment required to deploy the optimised main network. The Engineering Main Module contains four worksheets: *Main – Input, Main – Detail, Main – Collapsed* and *Main – Summary*. The following section describes each of the worksheets.

C.1   Description of Worksheets

C.1.1   Main – Input

135.   *Main – Input* contains the key design criteria for the main network. These rules are taken from the Dimensioning Rules Document developed by Telstra's engineering department. The Dimensioning Rules are designed to reflect the efficient engineering best practices and procedures for deploying a new ULL network. Many of these rules can be adjusted by the user in the input sheets incorporated into the user interface to the models[23]. The rules and model parameters that are included in the *Main – Input* worksheet are:

- the selection that specifies whether the module will design a main network for the ULL service (designated by a 1) or a network to provide basic access service (designated by a 2). (User Adjustable-UA);

- the main cable fill that is used to design the copper cable network in the main module (User UA);

- the multiplexing cabinet fill that is used to size the multiplexing equipment in the main module (UA);

- the maximum haul length for each size (number of pairs) and gauge of main copper cables, which is used to determine the maximum distance between cable joints (UA);

- the maximum haul length for each size (number of fibres) of main fibre cables, which is used to determine the maximum distance between cable joints (UA);

- the maximum allowable distance between manholes and pits in the main network (UA);

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23   Changes to these rules or parameters should be made in the inputs sheets incorporated into the user interface to the model. Input changes made directly into this module will not flow through to the Cost Calculation Module or results).

- the size of various conduit configurations that are used in deploying a main network;

- the size and capacities for multiplexers used in the model; and

- the size of the building terminal strips that are used to connect the building terminal to the network.

C.1.2   Main – Detail

136. *Main – Detail* contains the base data that has been extracted from Telstra's Cable Plant Records. This data is presented at the level of individual structure points within DAs. This worksheet performs a number of calculations that provide the basis for the plant quantity calculations undertaken in the *Main – Collapsed* worksheet. This worksheet also calculates the number and size of fibre multiplexing systems in the main network and size of all building terminals served by the main network.

C.1.2.1   Base Data

137. As noted above, the *Main - Detail* worksheet imports data from Telstra's records that are necessary to design an efficient network for providing ULL services. The data are extracted by structure point. A structure point is a physical component of the network (i.e. pillar, pit, manhole, lead-in or elevated joint). Each structure point is identified by a number. The efficient path that the main network takes from the pillars to the central office is determined by tracing existing cable routes through the various structure points. The base data for each structure point is identified in the first 11 columns of the *Main – Detail* worksheet and the headings for each of these columns are shaded in grey. The data that is extracted for each structure point is:

- ESA Code- The designation for the exchange in which the structure points reside;

- Existing Type of Cable – Identifies whether the segment is currently served by copper or fibre cables;

- Cable Number – Identifying number for the cable route;

- Cross Connect Point (CCP) – The pillar, building terminal or cabinet number that is being served by the cable route;

- Segment Length – The distance between the current structure and the next closest structure on the route back to the central office;

- Current Structure Number – The number used to identify the current structure point;

- Next Structure Number – The number used to identify the next structure point to which the current structure is connected on the path back to the central office (CO);

- Demand Served at CCP – The actual number of SIOs connected to the CCP (building terminal, cabinet or pillar);

- Total Distance from CO - The sum of all the segment lengths that are required to connect the current structure to the CO;

- Longest Cable in the Serving Area – This number is the longest distribution cable providing service in the distribution area being served by the CCP; and

- Segment Number – Identifies the number of cable segments required to connect the current structure point back to the CO.

138. The base data identified above allows the model to trace the efficient path from the CCP (pillar, cabinet or building terminal) to the serving exchange. These efficient paths are then combined to design an efficient main network for every exchange.

C.1.3   Main – Collapsed

139. *Main – Collapsed*, which collapses the distinct routes from each pillar to the exchange in the *Main – Detail* into a single main network. In this worksheet redundant routes are eliminated by combining the portions of each of the individual routes into a single route when they share a common path. In order to collapse the data for the numerous cable routes identified, the *Main – Collapsed* worksheet imports some of the same base data that is imported into the *Main – Detail* worksheet. The worksheet then calculates (1) the number, length and sizes of the copper cable and conduit runs required to serve the DAs, (2) the number of copper and fibre joints required at cable mergers or when the cable run exceeds its maximum haul distance, and (3) the number and size of pits and manholes required along the main conduit runs. Many of these volume calculations rely on values calculated in the *Main – Detail* worksheet.

C.1.3.1   Base Data

140. As noted above, the *Main - Collapsed* worksheet imports some base data from Telstra's records in order to collapse the routes identified on the *Main – Detail* worksheet. The data that is extracted for each exchange is:

- ESA Code- The designation for the exchange in which the structure points reside;

- Segment Length – The distance between the current structure and the next closest structure on the route back to the central office;

- Current Structure Number – The number used to identify the current structure point; and

- Next Structure Number – The number used to identify the next structure point to which the current structure is connected on the path back to the CO.

C.1.4   Main – Summary

141. *Main – Summary* presents the volume of plant, labour and equipment required in the distribution network summarised to the level of the ESA. The plant, labour and equipment in the *Main – Summary* worksheet is broken down into the following categories:

- Demand at Fibre Fed Pillars (See Section C.2);

- Length of Main Cables by Cable Type and Size (See Section C.3);

- Length of Main Conduit by Conduit Configuration (See Section C.4);

- Number of Main Pits and Manholes (See Section C.5);

- Number of Joints for Main Cable (See Section C.6);

- Count of Fibre MUX Equipment, for Both Field Size Units and Office Units (See Section C.7);

- Number of Pairs Terminating at ESA (See Section C.8); and

- Number of Building Terminals Served by Main Cable (See Section C.9).

142. The results for each category are accumulated in the *Main – Summary* worksheet at the level of the ESA. The data for each ESA is then transferred to the Cost Calculation Module prior to processing the data for another ESA.

143. The remainder of this section explains in detail how each of the above components of the distribution network is calculated. The relevant subsection for each component is shown in brackets in the list above. An index for the Main Module is provided in Attachment 2. This index provides cross-references between the model documentation and the Excel model for all input values, base data and calculated values. The index provides the name of the worksheet and the column or cell reference within the worksheet where each value can be found in the model. The index also identifies the paragraph number within this document where the explanation of calculated values is provided.

Figure 4: Main Network Architecture

Legend:

- ———— - Normal (.40 Gauge) Cable Route
- ———— - Heavy (.64 Gauge) Cable Route
- ⊗ - Pillar (900 or 1800)
- ▦ - Main Fed Building Terminal

- (P9) - Number 9 Pit (up to 2 way)
- [PF4] - PF4 Manhole (2-4 way)
- [PF12] - PF12 Manhole (4-12 way)
- [PF20] - PF20 Manhole (12-20 way)
- [PF28] - PF28 Manhole (20-28 way)
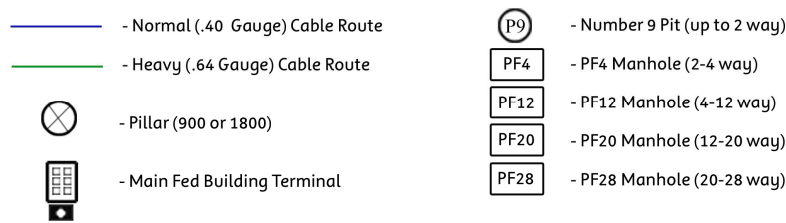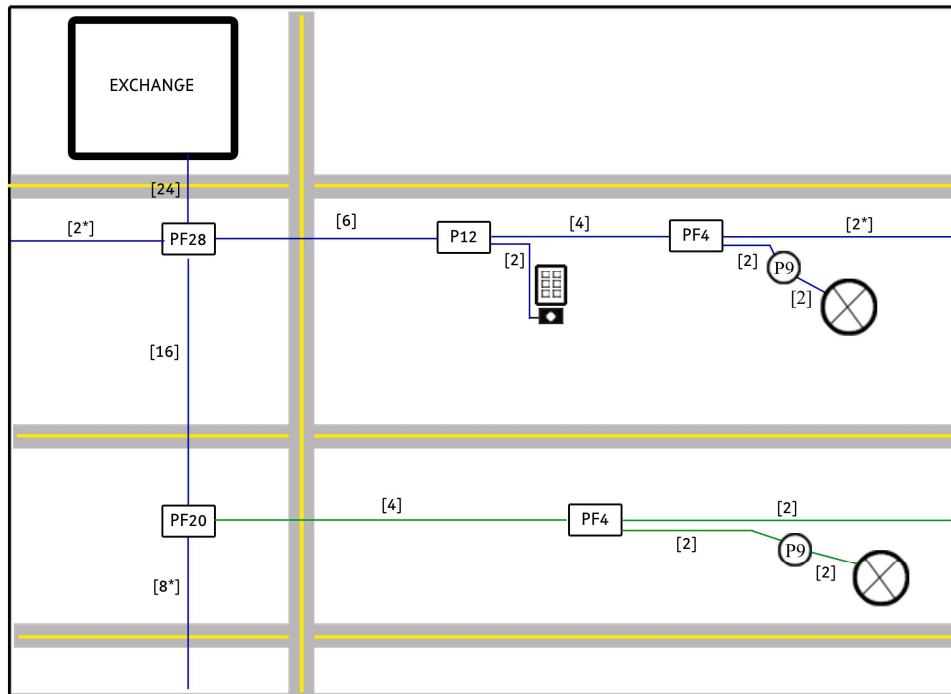
[#] - Conduit Configuration
*Conduits required for cable routes not shown in diagram

C.2   Demand at Fibre Fed Pillars

144.   In determining ULL costs for distribution plant, we need to know the number of customers that are served using only copper cables. The unit cost of the distribution network for a ULLS is calculated as total investment in DAs served by copper cables divided by the total demand in the DAs served by copper cables. To determine total demand in DAs served by copper cables, the Demand at Fibre Fed Pillars is deducted from the total demand in the exchange. Note that total demand is used when unitising the main network investments to account for the sharing that results when fibre and copper fed customers share the same main conduits.

145.   The Demand at Fibre Fed Pillars is calculated as IF(StudySelection = 1, SUMIF(Cable Gauge Indicator, "F", Demand Served at CCP) – SUMPRODUCT(Building Terminal Flag, Additional Fibre Cable Demand),0). This means that the number of customers served at fibre fed DAs is calculated as the total number of customers fed by fibre cable less those fibre fed customers who are served by a building terminal fed directly from the main

29

network (i.e. not in a distribution area) [24]. The Study Selection indicator identifies the type of network being modelled (i.e. 1 is ULLS, 2 is basic access service). Note that the demand served by fibre is only relevant in the calculation of the basic access service.

146. Cable Gauge Indicator is calculated as IF(Type of Cable Modelled= "Fibre", "F", IF(Heavy Gauge Cable Requirement > 0, "H", "N"))

147. For any given row, the formula returns the following:

- If the Type of Cable being Modelled is Fibre, the cell is assigned the code "F" (i.e. Fibre).

- Failing that, if the Heavy Gauge Cable Requirement is greater than zero, the cell is assigned the code "H" (i.e. Heavy Gauge Copper Cable).

- Otherwise, the cell is assigned the code "N" (i.e. Normal Gauge Copper Cable).

148. Building Terminal Flag is calculated as follows: IF(LEFT(Cable Number, 1)="T"), 1, 0). Therefore the Building Terminal Flag is set to 1 if the Cable Number begins with a "T" (indicating a main fed building terminal). Otherwise the formula returns a value of zero.

149. Type of Cable Modelled is calculated as IF(OR(Existing Type of Cable="Fibre", AND(CrossoverCode = "F", Total Distance from CO + Longest Cable in Serving Area >3,000)), "Fibre", IF(Current Structure Number = Origination Point, "Copper", Type of Cable Modelled previous row))

150. For any given row, the formula returns the following:

- The Type of Cable is set to "Fibre" if either:

  - The type of Type of Cable currently used to serve the distribution area (listed in the Base Data) is "Fibre", or

  - Both theCrossoverCode is "F" (the model is being used to calculate basic access service as opposed to ULL) and the sum of the Total Distance from CO and the Longest Cable in Serving Area (DA) is greater than 3.000 metres, the distance when fibre is used instead of copper in a basic access service network (Crossover Point);

- If neither of the above is applicable:

  - The Type of Cable is set to "Copper" if the Current Structure Number is the same as the Origination Point for the row. If it is the farthest structure from the central office on a specific cable run and it has not been deemed fibre based on the criteria listed above, then it will be designated copper.

  - Finally, if none of the above conditions apply, then the type of cable will be the same as the type of cable in the segment feeding the current structure (i.e. the whole run will use the same type of cable).

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[24]   See 3.3.2.1 of Dimensioning Rules Document

151. Additional Fibre Cable Demand is calculated a IF(Demand Served at CCP > 0, IF(Cable Gauge Indicator, "F" , Demand Served at CCP, 0),0). This formula identifies the demand at all the CCPs that are served by fibre. If the Cable Gauge Indicator is "F", meaning the model will use a fibre architecture to serve this CCP, then the demand in this column will equal the demand for the CCP.

C.3   Length of Main Cables by Cable Type and Size

152. The length of main cable is calculated separately for the two gauges of copper cable (Normal and Heavy) and for fibre cable. The length of cable is also calculated separately for each cable size. For Normal (.40 gauge) copper cables there are six possible cable sizes measured in terms of pairs: 2400, 1200, 800, 400, 200 and 100[25]. For Heavy (.64 gauge) copper cables there are five possible cable sizes measured in terms of pairs: 1200, 800, 400, 200 and 100[26]. For fibre cables there are seven possible cable sizes measured in terms of number of strands: 120, 60, 48, 36, 24, 12, and 6.

153. As with distribution cables, the calculation of the total length of main copper cables is a two step process which involves:

   • Identifying the number of cables at full capacity; and

   • Identifying the length of cables at less than full capacity.

154. This two step process is required to ensure all the cables are sized correctly to meet the existing demand.

155. The first step in calculating the length of main cable is to determine the number of fully utilised large cables. A cable is considered fully utilised when the actual demand being served divided by the design capacity (i.e. fill factor) is equal to the size of the cable. Note that the equation is only trying to identify the fully utilised large cables (i.e. 2400 pair .40 gauge cables, 1200 pair .64 gauge cables and 120 fibre cables) for each cable category[27]. The total length of fully utilised main cable is then derived by multiplying the total length of each segment by the number of fully utilised cables serving that segment.

156. The next step in the process is to determine the length of the cables required to serve the remaining capacity requirement on every route segment (i.e. demand not served by fully utilised cables). The residual capacity requirement is determined by deducting the demand served by fully utilised cables from the total demand on the cable segment. The size of cable needed to serve this residual demand is determined by identifying the cable size that is closest to but not less than the size required to meet the remaining demand.

157. The total length for fully utilised large cables is calculated as the sum of the length of fully utilised cables and the sum of the length of any additional large cables required to meet the remaining demand. The total length for smaller cable sizes is simply the sum, by cable size, of the lengths of the cables to serve the remaining demand. These calculations are set out in more detail below.

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[25]   See 3.3.2 of Dimensioning Rules Document
[26] See 3.3.2 of Dimensioning Rules Document
[27] See 3.3.2 of Dimensioning Rules Document

C.3.1   Calculation of the Total Length for Large Main Cables

158. The total length of large main cables is calculated for the largest size of each type of cable. The largest Normal copper cable (.40 gauge) is 2400 pairs, the largest Heavy copper cable (.64 gauge) is 1200 pairs and the largest fibre cable is 120 strands. The formula for calculating the total length of these cables is:

- .40 Gauge Large Main Cable is calculated as: SUMIF(Normal Cable Size (pairs), 2400, Segment Length)+SUMPRODUCT(Fully Utilised Large Copper Cables (.40 Gauge), Segment Length)

- .64 Gauge Large Main Cable is calculated as: SUMIF(Heavy Cable Size (pairs), 1200, Segment Length)+SUMPRODUCT(Fully Utilised Large Copper Cables (.64 Gauge), Segment Length)

- Fibre Large Main Cable is calculated as: SUMIF(Fibre Cable Size (strands), 120, Segment Length)+SUMPRODUCT(Fully Utilised Large Fibre Cables, Segment Length)

159. In these equations the total length of each type of large main cable is calculated as the sum of the segment lengths for the large main cables serving the remaining demand and the number of fully utilised large main cables times their associated segment length.

C.3.2   Number of Fully Utilised Main Cables

160. The number of fully utilised main cables is only calculated for the largest size of each type of cable.The formula for each is the same.

161. The number of Fully Utilised Large Copper Cables (.40 Gauge) is calculated as follows: IF(Cumulative .40 Gauge Cable Demand Segment > MaxNormalFeederCable, ROUNDDOWN(Cumulative .40 Gauge Cable Demand Segment / MaxNormalFeederCable, 0), 0). If the cumulative demand for .40 gauge cables (normal cables) is less than the maximum feeder cable size then there are no fully utilised large copper cables (.40 gauge). If the cumulative demand for .40 gauge cables exceeds the maximum feeder cable size (2400 pairs) then the number of fully utilised large copper cables (.40 gauge) is equal to the cumulative demand for .40 gauge cables divided by the maximum normal (.40 gauge) feeder cable size. This is rounded down to identify only the number of full cables.

162. The number of Fully Utilised Large Copper Cables (.64 Gauge) is calculated as IF(Cumulative .64 Gauge Cable Demand Segment > MaxHeavyFeederCable, ROUNDDOWN(Cumulative .64 Gauge Cable Demand Segment / MaxHeavyFeederCable, 0), 0). This formula calculates the number of fully utilised .64 copper cables in exactly the same way as the number of fully utilised .40 Gauge cables was calculated above except the maximum heavy feeder cable size is 1200 pairs.

163. The number of Fully Utilised Large Fibre Cables is calculated as: IF(Number of Fibre Strands > MaxFibreCable, ROUNDDOWN(Number of Fibre Strands / MaxFibreCable, 0), 0). This formula calculates the number of fully utilised fibre cables using a formula that is essentially the same as the formula .40 Gauge and .64 Gauge Cables discussed above except the demand is stated as number of fibres and the maximum fibre feeder cable size is 120 strands.

164. Cumulative .40 Gauge Cable Demand Segment is calculated as SUMPRODUCT((Current Structure Number *Main Detail* all rows= Current Structure Number *Main-Collapsed* current row)*(Next Structure Number *Main Detail* all rows= Next Structure Number

Main-Collapsed current row)*(.40 Gauge Cable Segment Demand *Main Detail* all rows). This formula sums the demand for .40 Gauge cable across all cable segments where the Current and Next Structure Numbers for all rows in the *Main - Detail* worksheet is equal to the Current and Next Structure Numbers for the current row in the *Main - Collapsed* worksheet. The Current and Next Structure Numbers define a route segment. The formula identifies all routes in the *Main – Detail* worksheet which pass through the current segment on the *Main – Collapsed* worksheet and sums the demand for .40 cables for each of these route segments to derive the total demand on the collapsed segment.

165. A similar calculation is performed for heavy copper cables as follows: Cumulative .64 Gauge Cable Demand Segment is calculated as SUMPRODUCT(Current Structure Number *Main Detail* all rows= Current Structure Number *Main-Collapsed* current row)*(Next Structure Number *Main Detail* all rows= Next Structure Number *Main-Collapsed* current row)*(.64 Gauge Cable Segment Demand *Main Detail* all rows). Again the formula combines the demand for every route segment identified in the *Main – Detail* worksheet, which passes through the collapsed segment.

166. Number of Fibre Strands is calculated as SUMPRODUCT(Current Structure Number *Main Detail* all rows= Current Structure Number *Main-Collapsed* current row)*(Next Structure Number *Main Detail* all rows= Next Structure Number *Main-Collapsed* current row)*(Number of Fibres *Main Detail* all rows). This equation sums all the fibre strands that pass through a route segment. Although this equation is very similar to the copper cable calculations identified above there is one difference. Unlike the copper cable calculation, the fibre calculation identifies demand as the number of fibre strands required as opposed to customers being served. Number of fibre strands is dictated by the number of multiplexing systems that are fed by the main cable run. Each multiplexer requires two fibre strands and can serve a wide range of customers. Hence, it is the demand for multiplexers that guides the demand for fibres.

167. The Lookup Key formula combines the Current Structure Number and Next Structure Number for every cable segment. This key is then used to identify all routes that run between the same two points so that the cable segments can be combined.

168. .40 Gauge Cable Segment Demand is calculated as IF(Current Structure Number current row = Origination Point, IF(Cable Gauge Indicator<> "F", IF (Current Structure Number current row = Origination Point, SUMPRODUCT((Termination Point all rows = Current Structure Number current row)*(Additional .40 Gauge Cable Demand all rows)), 0) + Additional .40 Gauge Cable Demand current row),IF(AND(.64 Gauge Cable Segment Demand previous row > 0, .64 Gauge Cable Segment Demand current row = 0), .64 Gauge Cable Segment Demand previous row + .40 Gauge Cable Segment Demand previous row, .40 Gauge Cable Segment Demand previous row)).

169. This calculation identifies the demand on any segment of a cable route. If the current structure is at the start of the cable route (i.e. at the pillar, building terminal or cabinet being served by the cable run), and the cable is not fibre then the normal cable demand at the current structure is added to any demand coming into the structure from any other subordinate pillars, cabinets or building terminals to determine the total demand on the segment. Demand coming into a structure from subordinate structures (i.e. demand entering a cabinet from one or more subordinate building terminals or pillars) can be identified by the fact that the terminating point for the subordinate cable run is the same as the current structure number for the cable segment for which demand is being calculated. Note that in the SUMPRODUCT calculation if a statement is true .e.g. Terminating Point = Current Structure Number) a value of one is assigned to the calculation.

170. If the current structure is not the Origination Point for the cable run the demand for the segment will be set equal to the demand for the prior segment. This is because, with the exception of the following discussion, each cable serves only one structure, so

demand can only enter that route at that structure (Note that in the *Main - Detail* worksheet all cable routes serve only one structure. These routes are combined into larger routes serving many structures on the *Main – Collapsed* worksheet).

171. The one exception to this rule is when a .64 gauge cable is converted to a .40 gauge cable. When a customer location is further from the central office than the transmission limits for .40 gauge cable, .64 gauge cable must be placed within the main network to bring the service back into an acceptable range. The .64 gauge cable starts at the pillar and runs back towards the central office until there has been enough cable laid to bring the customer's service back into acceptable transmission limits. When this occurs, the .64 gauge cable is converted to .40 gauge cable. The model identifies when this occurs by finding any point where the .64 Gauge Cable Segment Demand drops from a positive amount on the previous segment to no demand on the current segment. When this occurs the heavy and normal gauge cable demand for the prior segment are combined.

172. .64 Gauge Cable Segment Demand is calculated as IF(Current Structure Number current row = Origination Point, IF(Cable Gauge Indicator<> "F", IF(Current Structure Number current row = Origination Point, MAX(0, SUMPRODUCT((Termination Point all rows = Current Structure Number current row) * (Additional .64 Gauge Cable Demand all rows)) - SUMPRODUCT((Termination Point all rows = Current Structure Number current row) * (Additional .40 Gauge Cable Demand all rows))), 0) + , Additional .64 Gauge Cable Demand current row, 0), IF(Cable Gauge Indicator= "H", .64 Gauge Cable Segment Demand previous row, IF(AND(.64 Gauge Cable Segment Demand previous row > 0, COUNTIF(Termination Point all rows, Origination Point current row) > 0), IF(SUMIF(Next Structure Number, Origination Point, Heavy Gauge Cable Requirement) / COUNTIF(Next Structure Number, Origination Point) – (SUMIF(Current Structure Number, Origination Point next row, Total Distance from CO) / COUNTIF(Current Structure Number, Origination Point) – Total Distance from CO next row) > 0, .64 Gauge Cable Segment Demand previous row, 0), 0))).

173. The first portion of this calculation is virtually identical to the first portion of the calculation used to identify .40 gauge cable demand on a segment. If the current structure is at the start of the cable route, and the cable is not fibre then the heavy cable demand at the current structure is added to any heavy cable demand coming into the structure from any other subordinate pillars, cabinets or building terminals to determine the total demand on the segment.

174. If the current structure is not the Origination Point for the cable run and the Cable Gauge Indicator for the segment is "H" (i.e. heavy), the heavy gauge cable demand for the segment will be set equal to the demand for the prior segment.

175. The last portion of the calculation identifies the heavy gauge cable demand for cable runs going from a cabinet back to the central office. The model does this by first determining if a cable run starts at a cabinet where demand from two or more subordinate structures has been combined. If there are one ore more cable segments with Next Structure Numbers that are identical to the Origination Point for a cable run, the cable run is starting at a cabinet. If there is a heavy gauge cable requirement at the cabinet the model determines the length of that requirement by averaging the length of the Heavy Gauge Cable Requirements for all the cable routes feeding the cabinet. For each cable segment from the cabinet to the exchange the total distance from the cabinet to the end of each cable segment is deducted from the total length of heavy gauge cable required at the pillar. If the total heavy gauge requirement at the cabinet is greater than the distance from the cabinet to the end of the current segment, the model places additional heavy gauge cable in the segment. Once the distance from the cabinet exceeds the length of heavy gauge cable required at the cabinet, the heavy gauge cable requirement for the segment is set to zero.

176. Fibre Cable Segment Demand is calculated as follows: IF(Current Structure Number = Origination Point, IF(Cable Gauge Indicator= "F", SUMIF(Termination Point, Current Structure Number, Additional .40 Gauge Cable Demand) + SUMIF(Termination Point, Current Structure Number, Additional .64 Gauge Cable Demand) + SUMIF(Termination Point, Current Structure Number, Additional Fibre Cable Demand) + Additional Fibre Cable Demand, SUMIF(Termination Point, Current Structure Number, Additional Fibre Cable Demand) + Additional Fibre Cable Demand), Fibre Cable Segment Demand previous row). This calculation is very similar to the calculations used to identify .40 gauge cable demand, with a few exceptions. The calculation identifies the fibre demand on any segment of a cable route using a similar process. If the current structure is at the start of the cable route, and the cable is fibre then the fibre cable demand at the current structure is added to any copper cable and fibre cable demand coming into the structure from any other subordinate pillars, cabinets or building terminals to determine the total demand on the segment.

177. Note that at a cabinet, demand from both copper and fibre routes can be aggregated onto a single fibre route. This formula calculates the combined demand coming from all routes feeding the structure. The model identifies demand served by the structure by determining if the Origination Point structure number is the same as the current structure number. The demand at this point is then added to demand coming from subordinate cable runs, which is determined by summing demand on all routes with a Termination Point that's equal to the current structure point. If the cable route ends at a cabinet, the Termination Point for that route will be the current structure number for the cable segment connected to the cabinet.

178. If the current structure is not the Origination Point for the cable run the demand for the segment will be set equal to the demand for the prior segment.

179. Origination Point is calculated as IF(Cross Connect Point current row <> Cross Connect Point previous row, Current Structure Number, Origination Point previous row). This formula identifies the structure number for the CCP where the cable route originates. In the *Main – Detail* worksheet, all the segments of a cable route are in sequential order by row, with the first segment or structure point being at the CCP. Consequently, when the CCP designator changes (i.e. is not the same as the prior row) the originating structure point for a new cable route is identified. The above formula simply defines the structure point where this transition occurs as the origination point for the whole cable segment. If the segment is not the originating segment for the route, the originating point is set equal to the structure point for the prior line, keeping the originating point constant for the whole cable run.

180. Termination Point is calculated as IF(AND(Segment Number current row > Segment Number next row, ISNUMBER(Segment Number next row)), Termination Point next row, Next Structure Number). The termination point is the last structure in the route. The formula looks up whether the segment number for the current structure is the last one in the route. The segment numbers count down from the CCP to the point closest to the central office. If the segment number for the next row is less than the segment number for the current row, the next segment is on the same route. This occurs until the countdown reaches the last segment (i.e. closest to the central office) where the segment number is equal to one. The next segment number will be the start of a new segment and will be greater than one. Therefore, when the next segment number is greater than the current segment number we are on the last segment on the route and the terminating structure for that segment (i.e. Next Structure Number) is the terminating structure (i.e. Termination Point) for the route. The model then sets the Termination point for all other segments on the route equal to the Termination point for the last structure on the route.

181. Additional .40 Gauge Cable Demand is calculated as IF(Demand Served at CCP > 0, IF(Cable Gauge Indicator="N", ROUNDUP(Additional Capacity Requirement, -2), 0),

IF(AND(Cross Connection Point (CCP) previous line = Cross Connection Point current line, Cable Gauge Indicator previous line is "H" (heavy), Cable Gauge Indicator current line is "N" (normal), SUMIF(Current Structure Number all rows, Origination Point, Additional .64 Gauge Cable Demand), 0)). If Demand Served at the Cross Connect Point (CCP) is greater than zero, and normal copper cable is required to serve the segment, then the demand for normal cable (i.e. .40 gauge cable) is equal to the level of additional capacity required, rounded up to the nearest 100, as main cable has a minimum size of 100 pair. If there is no demand at the CCP then the additional demand for normal copper cables is set at zero unless the previous line had a was on the same cable run (i.e. served by the same CCP) and had a heavy cable demand that does not exist on the curent line or cable segment. If these conditions exist, the .64 cable demand on the previous cable segment is converted to a .40 cable demand on the current segment.

182. Additional .64 Gauge Cable Demand is calculated as IF(Demand Served at CCP > 0, IF(Cable Gauge Indicator="H", ROUNDUP(Additional Capacity Requirement, -2), 0), 0). This calculation is virtually identical to the Additional .40 Gauge Cable Demand with the lone exception that it looks for demand which will be served by "H" as opposed to "N" normal cable.

183. Additional Capacity Requirement is calculated as: IF(Current Structure Number = Origination Point, IF(Building Terminal Flag = 1, Demand Served at CCP, Demand Served at CCP / FeederFill), 0). This formula calculates the capacity required at the beginning of each cable segment (i.e. where the Current Structure Number is equal to the Origination Point). If the cable segment is connected to a building terminal then the capacity required is equal to the level of demand served at the CCP (that is, building terminals are modelled at their current size). If the cable segment is not connected to a building terminal then the capacity required is equal to the demand served at the CCP divided by the fill factor. If it is not the beginning of a cable segment, no demand is identified.

184. Number of Fibres is calculated as IF(Fibre Cable Segment Demand > 0, IF(Fibre Cable Segment Demand >= Max_CMUX, ROUNDDOWN(Fibre Cable Segment Demand / Max_CMUX, 0) * MaxCMUXFibre + INDEX(CMUXFibreRange, MATCH(Fibre Cable Segment Demand – (ROUNDDOWN(Fibre Cable Segment Demand / Max_CMUX, 0) * Max_CMUX), SystemCapacityRange, -1)), INDEX(CMUXFibreRange, MATCH(Fibre Cable Segment Demand, SystemCapacityRange, -1))), 0). If there is a fibre cable demand on a particular cable route, the above formula calculates the number of fibres required in the cable route.

185. The first step is to determine if any large fully utilised CMUXs will be required to serve the demand on the segment (i.e. the demand for the segment exceeds the maximum capacity for a large multiplexer). If large fully utilised CMUXs are required, the number of them is identified as total demand segment divided by the maximum capacity of a large CMUX rounded down to the nearest whole number. This amount is then multiplied by the number of fibres required to serve a large CMUX.

186. The next step is to identify the size and type of CMUXs required to serve any demand not being met by large CMUXs. This is accomplished by determining the remaining demand on the route that is in excess of the demand being met by fully utilised large multiplexers. The remaining capacity is then used lookup the number of fibres that would be required for the size of CMUX that is needed to serve the remaining demand. Note that in the model all CMUX sizes are connected to the exchange using 2 fibres[28].

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[28]   See Section 3.3.5 of the Dimensioning Rules document.

187. Finally, if no large fully utilised CMUXs are required to serve the segment demand, and the segment is served by fibre, the number of required fibres in the segment is set at 2 using the same equation as above.

188. Heavy Gauge Cable Requirement is calculated as IF(Type of Cable Modelled= "Fibre", 0, MAX(0, IF(Cross Connect Point for the current row <> Cross Connect Point previous row, ((Total Distance from CO + Longest Cable in Serving Area)/1000*2.68-11.61)*1000, Heavy Gauge Cable Requirement previous row-Segment Length previous row))

189. This formula takes the maximum of the following:

- Zero;

- If the row is the start of a cable route (i.e. Cross Connect identifier changed from the previous row), the length (in kilometres) of heavy gauge cable required is determined as the sum of Total Distance from CO and the Longest Cable in Serving Area (DA), multiplied by 2.68, minus 11.61. The derivation of this formula is found Section 3.1.1.2 of the Dimensioning Rules and calculates the total length of .64 gauge cable that will be required in the cable route. As stated in the Dimensioning Rules, the model will assume that the total length of .64 gauge cable required will be placed starting at the CCP. As the cable route progresses towards the central office the length of additional .64 gauge cable required is reduced by the length of each cable segment where the model uses point .64 gauge cables. Consequently the .64 cable required for any structure, other than the CCP, is calculated by taking the Heavy Gauge Cable Requirement for the previous row and deducting the segment length for the previous row.

C.3.3 Length Other Sizes of Main Cable (i.e. Not Large Cables)

190. Once the length for the large cables is determined the model calculates the length for all other sizes of main cables. This is accomplished by summing the cable lengths for each size of copper cable (pairs) or fibre cable (strands).

191. The formula for copper main cable lengths for remaining demand are as follows:

- SUMIF(Normal Cable Size (pairs), x, Segment Length)

- SUMIF(Heavy Cable Size (pairs), x, Segment Length)

192. Note that this equation is identical to the portion of the large cable formula that identifies the large cable length to serve remaining demand. The formula simply sums all cable segments lengths for all cables that are the same size, where x is the number of pairs ranging from 1200 to 100.

193. For fibre main cables, the lengths are differentiated by cable size in terms of number of strands (i.e.120, 60, 48, 36, 24, 12, 6). The formula for identifying fibre main cable lengths for all cables other than the large fibre cable (i.e. 120) is as follows:

- SUMIF(Fibre Cable Size (strands), y, Segment Length)

194. Where y is the number of strands ranging from 60 strands to 6 strands.

195. Normal Cable Size (pairs) is calculated as follows: IF(AND(Cumulative .40 Gauge Cable Demand Segment > 0, Fully Utilised Large Copper Cables (.40 Gauge) * MaxNormalFeederCable - Cumulative .40 Gauge Cable Demand Segment < 0), INDEX(NormalCopperFeederCableRange, MATCH(Cumulative .40 Gauge Cable Demand Segment - Fully Utilised Large Copper Cables (.40 Gauge) * MaxNormalFeederCable,

NormalCopperFeederCableRange, -1)), 0). The calculation first determines if there is any demand not being served by fully utilised large copper cables (i.e. remaining demand). If there is remaining demand, the formula calculates the amount of remaining demand by deducting the demand served by fully utilised large (i.e. 2400 pair) copper cables from the total demand on the segment. The formula then uses the remaining demand and the NormalCopperFeederCable Range to identify the smallest cable that would be capable of serving the total remaining demand.

196. The cable sizes for Heavy copper cable and fibre are calculated using the same basic formula as follows:

- Heavy Cable Size (pairs) = IF(Cumulative .64 Gauge Cable Demand Segment > 0, INDEX(HeavyCopperFeederCableRange, MATCH(Cumulative .64 Gauge Cable Demand Segment - Fully Utilised Large Copper Cables (.64 Gauge) * MaxHeavyFeederCable, HeavyCopperFeederCableRange, -1)), 0).

- Fibre Cable Size (strands) = IF(Number of Fibre Strands > 0, INDEX(FibreCableRange, MATCH(Number of Fibre Strands - Fully Utilised Large Fibre Cables * MaxFibreCable, FibreCableRange, -1)), 0).

C.4   Length of Main Conduit by Conduit Configuration

197. The Length of Main Conduit is determined for each of the nine different conduit configurations employed in the model. The conduit configurations are differentiated by the number of conduits in the route (i.e. 24, 20, 16, 12, 8, 6, 4, 2, or 1) [29]. The formula for calculating the length of main conduit is the same for all configurations:

- SUMIF(Number of Conduits Required, x, Segment Length).

198. Where x takes one of 9 values ranging from 24 to 1. Therefore, the total conduit length for the ESA for each size conduit configuration is simply the sum of the segment lengths for all segments in the ESA served by a specific sized configuration.

199. Number of Conduits Required is calculated as IF(Number of Cables in Section >= Max_Number_of_Conduits, Max_Number_of_Conduits, INDEX(ConduitConfigurationRange, MATCH(Number of Cables in Section + 1, ConduitConfigurationRange, -1))). In the main cable route there is one conduit for every copper cable and one spare conduit for maintenance[30]. The calculation identifies the conduit configuration that is required by totalling the number of cables in the segment plus one additional maintenance conduit. The formula then looks up the smallest conduit configuration that can accommodate the conduit requirement calculated above. The only exception is for the instance when the size of the conduit configuration required (i.e. number of cables +1) exceeds the largest conduit configuration in the model (i.e. 24), then the size of the conduit configuration is set equal to the largest configuration in the model. This is a conservative assumption which eliminates the need to build into the model every potential conduit configuration.

200. Number of Cables in Section is calculated as SUM(Fully Utilised Large Copper Cables (.40 Gauge), Fully Utilised Large Copper Cables (.64 Gauge), Fully Utilised Large Fibre Cables) + 3 – COUNTIF(Normal Cable Size (pairs), Heavy Cable Size (pairs), Fibre Cable Size

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[29]   See 3.3.3.1 of Dimensioning Rules Document
[30]   See 3.3.3.1 of Dimensioning Rules Document

(strands), 0). Therefore, the number of cables in a section is equal to the number of fully utilised large cables plus the number of cables used to accommodate demand in excess of that carried on fully utilised cables.

C.5   Number of Pits and Manholes

201. The Number of Pits and Manholes required in the main network are differentiated in the model by the size of the manhole or pit. The size of manholes in the model are number 28, 20, 12 or 4 manholes and the only size of pit used in the main network is a number 9 pit[31]. Manholes or pits are required at cable mergers, pillars, main fed building terminals and at distances that exceed the maximum manhole spacing. The formula for calculating the total number of each type of pit and manhole bye ESA in the model is as follows:

- SUMIF(Manhole Size (Mergers), x, Manholes at Cable Mergers) + SUMIF(Manhole Size (Distance), x, Distance Manholes).

202. Where x designates one of four manhole sizes or a number 9 pit. Therefore, the total number of each size of pit and/or manhole required in the main network is calculated as the sum of number of each type of manholes/pits required at cable mergers and the sum of the number of each type of manholes/pits required at maximum manhole/pit distances.

C.5.1   Pits and Manholes at Cable Mergers and Pillars

203. Manhole Size (Mergers) is calculated as IF(Manholes at Cable Mergers > 0, INDEX(ManholeSizingRange, IF(Manhole Sizing Index (Mergers) => Max_Number_of_Conduits, 1, MATCH(Manhole Sizing Index (Mergers)), ManholeSizingRange, -1))), 0). This formula checks if there are any manholes or pits required at cable mergers and, if so, uses the Manhole Sizing Index (Mergers) to lookup in the manhole sizing range the smallest pit/manhole capable of meeting the demand at this merger. However, if the manhole required is larger than the ones incorporated into the model (i.e. 24), then the size of the Manhole is set equal to the largest manhole in the model. This again is a conservative simplifying assumption which eliminates the need to build all potential manhole sizes into the model.

204. Manholes at Cable Mergers is calculated as IF(AND(Branches Feeding Current Structure = 1, Cumulative .40 Gauge Cable Demand Segment = .40 Gauge Cable at Mergers, Cumulative .64 Gauge Cable Demand Segment= .64 Gauge Cable at Mergers, Cumulative Fibre Cable Demand Segment = Fibre Cable at Mergers), 0, IF(Manhole Key = 1, 1, 0)). If the cables coming into a structure are equal to the cumulative number of cables on the segment and they are coming from only one other structure, no manhole is required. However if the cumulative cable demand at the segment did not come from another structure (i.e. was at the beginning of the route) or there are more than two structures feeding the current structure (i.e. a merger of two or more routes), a manhole or pit is required.

205. Manhole Sizing Index (Mergers) is calculated as SUMIF(Current Structure Number, Current Structure Numbe, Number of Conduits Required) * Manholes at Cable Mergers. This formula sums the number of conduits entering each current structure if the structure is at a cable merger. If there is no need for a cable merger manhole, the value for Manholes at Cable Mergers will be equal to zero resulting in a Manhole Sizing Index of 0 (i.e. no manhole required).

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[31]   See 3.3.4 of Dimensioning Rules Document

206. Branches Feeding Current Structure is calculated as COUNTIF(Next Structure Number, Current Structure Number). The calculation identifies the number of subordinate structures (i.e. structures with cables running into the current structure) for each structure in the exchange. If the next structure number for one row is equal to the current structure number for the current row, then the cable from that structure is running to the current structure. By summing these occurrences it is possible to determine how many cables are coming into the current structure from other structures. If there are mulitiple cables coming into the current structure then the structure is at a cable merger.

207. .40 Gauge Cable at Mergers is calculated as SUMIF(Next Structure Number, Current Structure Number, Cumulative .40 Gauge Cable Demand Segment). This formula sums the cumulative demand for .40 gauge copper cable entering a given structure from any subordinate structures.

208. There are similar calculations for .64 gauge copper cable and fibre:

- .64 Gauge Cable at Mergers is calculated as SUMIF(Next Structure Number, Current Structure Number, Cumulative .64 Gauge Cable Demand Segment)

- Fibre Cable at Mergers is calculated as SUMIF(Next Structure Number, Current Structure Number, Cumulative Fibre Cable Demand Segment

209. Cumulative Fibre Cable Demand Segment is calculated as SUMPRODUCT(Current Structure Number *Main Detail* all rows= Current Structure Number *Main-Collapsed* current row)*(Next Structure Number *Main Detail* all rows= Next Structure Number *Main-Collapsed* current row)*(Fibre Cable Segment Demand *Main Detail* all rows). Much like the formulas for calculating cumulative copper cable demand segment discussed in Section C.3.2. The formula sums the total demand on the *Main – Detail* worksheet for all cable segments with the same starting and ending points (i.e. structure numbers).

210. Manhole Key is calculated as IF(COUNTIF(Current Structure Number first row : Current Structure Number current row, Current Structure Number current row) > 1, 0, 1). This formula looks through the current structure numbers in all previous rows to determine whether the current structure number in the current row is the first occurrence of that structure number. If it is then the first manhole occurrence is set to 1, otherwise, it is set to zero.

C.5.2   Pits and Manholes at Distance Limitations

211. Manhole Size (Distance) is calculated as IF(Distance Manholes > 0, INDEX(ManholeSizingRange, Manhole Sizing Index (Distance), 0). If there is a need for a distance manhole then the size of that manhole is determined by looking up the manhole size in the manhole sizing range using the Manhole Sizing Index (Distance).

212. Manhole Sizing Index (Distance) is calculated IF(Number of Conduits Required >= Max_Number_of_Conduits, 1, MATCH(Number of Conduits Required, ManholeSizingRange), 0). This formula uses the number of conduits required to look up the index for the smallest manhole or pit capable of accommodating the required conduits. If the number of conduits required exceed the capacity of the larges sized manhole, the model uses the largest size manhole sizing index available. Note that the manhole sizing index for distance manholes is 1 through 5 for 24, 20, 12 and 4 size manholes and number 9 pits, respectively.

213. Distance Manholes is calculated as ROUNDDOWN((Distance From Last Manhole) / INDEX(ManholeSpacingRange, Manhole Sizing Index (Distance), 0). This formula calculates the number of distance manholes required as the segment length plus the

distance from the previous section divided by the maximum distance between manholes (250 metres). The result is rounded down, as distance manholes are only required when the full 250 metres is exceeded.

214. Distance From Last Manhole is calculated as IF(AND(Branches Feeding Current Structure = 1, Manhole Key = 1, Manholes at Cable Mergers = 0),Current Segment Length + IF(SUMIF(Next Structure all rows, Current Structure current row, Distance Manholes) = 0, SUMIF(Next Structure all rows, Current Structure current row, Distance From Last Manhole), SUMIF(Next Structure all rows, Current Structure current row, Distance From Last Manhole) - SUMIF(Next Structure all rows, Current Structure current row, Distance Manholes) * INDEX(ManholeSpacingRange, Manhole Sizing Index (Distance)))), 0). The calculation first ensures the current structure point was not evaluated on a prior row (i.e. was the first occurrence of a manhole), that a mergers manhole has not already been placed at the current structure and that a distance manhole was not placed on the segments leading into the current structure. If all of the above qualifiers are true, the Distance from Last Manhole is set at the length of the current segment plus the distance from the last manhole for the cable segment feeding the current structure. However, if distance joints are placed in the current segment, the above formula is revised to reduce the total length of the segment, as calculated above, by the number of distance pits or manholes times the maximum manhole spacing distance for that size of pit or manhole. This distance is then added to subsequent cable segments until the manhole spacing parameters are again exceeded.

C.6   Number of Joints Main Cable

215. The number of joints for large copper and fibre cables is calculated as the number of fully utilised large cables multiplied by the total number of joints for these large cables plus the sum of the joints for all large cables used to serve remaining demand (i.e. demand not being met by fully utilised large cables). Note that the calculation simply sums the total number of large cables at any point where a joint is required. The calculation is done separately for Normal, Heavy and Fibre cable as follows:

- Number of Joints Normal .40 Gauge Cable (2400 Pair) = SUMPRODUCT(Fully Utilised Large Copper Cables (.40 Gauge) * Total Joint .40 Gauge Cable) + SUMIF(Normal Cable Size (pairs), 2400, Total Joint .40 Gauge Cable)

- Number of Joints Heavy .64 Gauge Cable (1200Pair) = SUMPRODUCT(Fully Utilised Large Copper Cables (.64 Gauge) * Total Joint .64 Gauge Cable + SUMIF(Heavy Cable Size (pairs), 1200, Total Joint .64 Gauge Cable)

- Number of Joints Fibre Cable (120 Fibre) = SUMPRODUCT(Fully Utilised Large Fibre Cables * Total Joint Fibre Cable) + SUMIF(Fibre Cable Size (strands), 120, Total Joint Fibre Cable)

216. The number of joints for all other sizes of copper and fibre cables is calculated as the sum of the number of cables at any joint that are needed to serve remaining demand (i.e. demand not being met by large fully utilised large cables). These calculations are done separately for each size of Normal, Heavy and Fibre cables as follows:

- Number of Joints Normal .40 Gauge Cable = SUMIF(Normal Cable Size (pairs), x, Total Joint .40 Gauge Cable)

- Number of Joints Heavy .64 Gauge Cable = SUMIF(Heavy Cable Size (pairs), y, Total Joint .64 Gauge Cable)

- Number of Joints Fibre Cable = SUMIF(Fibre Cable Size (strands), z, Total Joint Fibre Cable)

217. Note that the above equations are identical to the second part of the equations for determining the number of joints for large cables. The x, y, and z in the above equations represent the various sizes (except for the largest size) of normal copper, heavy copper and fibre cables, respectively.

218. The total number of joints is the sum of distance cable joints, joints at pillars and joints at mergers and is calculated as follows:

- Total Joint .40 Gauge Cable is calculated as .40 Gauge Cable Joint at Mergers + .40 Gauge Cable Joint at Pillar + .40 Gauge Distance Joints Less Than Full Cables. Therefore, the formula calculates the total number of joints as the joint at mergers plus the distance joints

- Total Joint .64 Gauge Cable is calculated as .64 Gauge Cable Joint at Mergers + .64 Gauge Cable Joint at Pillar + .64 Gauge Distance Joints Less Than Full Cables

- Total Joint Fibre Cable is calculated as Fibre Cable Joints at Mergers + Fibre Cable Joint at Pillar + Fibre Distance Joints for Less Than Full Cables

C.6.1 Number of Cable Joints at Mergers

219. .40 Gauge Cable Joint at Mergers is calculated as IF(Cumulative .40 Gauge Cable Demand Segment > 0, IF(Branches Feeding Current Structure = 1, IF(SUMIF(Next Structure Number all rows, Current Structure Number current row, Cumulative .40 Gauge Cable Demand Segment all rows) = Cumulative .40 Gauge Cable Demand Segment current row, 0, 1), IF(Branches Feeding Current Structure = 0, 0, 1)), 0). This formula puts a joint at every structure where there is more than one branch coming into the structure from subordinate pits (i.e. a cable merger). It also places a joint at any structure where the number of cables entering the structure is greater than the number of cables exiting the structure (e.g. where .64 gauge cables convert to .40 gauge cables).

220. Similar formulas are used to determine joints at mergers for heavy copper and fibre cables:

- .64 Gauge Cable Joint at Mergers is calculated as IF(Cumulative .64 Gauge Cable Demand Segment> 0, IF(Branches Feeding Current Structure = 1, IF(SUMIF(Next Structure Number all rows, Current Structure Number current row, Cumulative .64 Gauge Cable Demand Segment all rows) = Cumulative .64 Gauge Cable Demand Segment, 0, 1)), IF(Branches Feeding Current Structure = 0, 0, 1)), 0).

- Fibre Cable Joints at Mergers is calculated as IF(Cumulative Fibre Cable Demand Segment > 0, IF(Branches Feeding Current Structure = 1, IF(SUMIF(Next Structure Number all rows, Current Structure Number current row, Cumulative Fibre Cable Demand Segment all rows) = Cumulative Fibre Cable Demand Segment 0, 1), IF(Branches Feeding Current Structure = 0, 0, 1)), 0).

221. .40 Gauge Cable Joint at Pillar is calculated as IF(AND(Cumulative .40 Gauge Cable Demand Segment > 0, Branches Feeding Current Structure < 1), 1, 0). This formula puts a joint at every structure where the main cable merges with the cable from the pillar. If no cables are coming from a prior structure and there is demand on the segment, the segment is the connection between the pillar and the main network and a joint is needed to connect the main cable to the pillar.

222. Similar formulas are used to determine joints at pillar mergers for heavy copper and fibre cables:

- .64 Gauge Cable Joint at Pillar is calculated as IF(AND(Cumulative .64 Gauge Cable Demand Segment> 0, Branches Feeding Current Structure < 1), 1, 0).

- Fibre Cable Joint at Pillar is calculated as IF(AND(Cumulative Fibre Cable Demand Segment > 0, Branches Feeding Current Structure < 1), 1, 0).

C.6.2   Number of Distance Joints for Main Cables

223. A distance joint is required if the distance between joints exceeds the maximum haul length for the size of cable being placed.

224. .40 Gauge Distance Joints Less Than Full Cables is calculated as IF(Normal Cable Size (pairs) > 0, ROUNDDOWN(Segment Length / INDEX(NormalCopperFeederLengthRange, MATCH(Normal Cable Size (pairs), NormalCopperFeederCableRange, -1), 0), 0), 0). If there is normal (i.e. .40 gauge) copper cable running through the segment, the number of distance joints required is calculated as the segment length divided by the maximum haul distance for the size of cable being placed, rounded down to the nearest whole number.

225. The formulas for calculating the number of distance joints for heavy gauge and fibre cables are essentially the same as the above formula for normal .40 gauge cables. These formulas are:

- .64 Gauge Distance Joints Less Than Full Cables is calculated as IF(Heavy Cable Size (pairs) > 0, ROUNDDOWN(Segment Length / INDEX(HeavyFeederCableLengthRange, MATCH(Heavy Cable Size (pairs), HeavyCopperFeederCableRange, -1), 0), 0), 0);

- Fibre Distance Joints for Less Than Full Cables is calculated as IF(Fibre Cable Size (strands)> 0, ROUNDDOWN(Segment Length / INDEX(FibreCableLengthRange, MATCH(Fibre Cable Size (strands), FibreCableRange, -1), 0), 0), 0);

C.6.3   Branch Kits

226. A branch kit is required for each joint at a cable merger and hence the formula for calculating the number of branch kits is simply the sum of the number of cable joints (i.e. number of cables that are joined) at cable mergers for each cable type across the whole ESA:

- Branch Kits for Normal Copper Cable = SUM(.40 Gauge Cable Joint at Mergers)

- Branch Kits for Heavy Copper Cable = SUM(.64 Gauge Cable Joint at Mergers)

- Branch Kits for Fibre Cable = SUM(Fibre Cable Joints at Mergers)

C.7   Count of Fibre CMUX Equipment, for Both Field Units and Office Units

C.7.1   Field units

227. There are two sizes of remote (i.e. in the field) multiplexing systems in the model. Both units are from Alcatel and one (i.e. System 1) has a maximum capacity of 786 while the second unit (i.e. System 2) has a maximum capacity of 384 services[32]. In practice, these

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[32] See 3.3.5 of Dimensioning Rules Document

systems will never operate at full capacity, due to the need for spare capacity for maintenance and other network needs (i.e. a design fill factor of less than 100%).

228. The model first calculates the number of fully utilised large System 1 CMUXs and then the number of CMUXs required to meet the remaining demand (i.e. demand not met by the fully utilised large CMUXs. The formulas for calculating the number of System 1 and 2 CMUXs required are as follows:

- System 1 MUXs = SUM(Number of Max CMUX Systems) + COUNTIF(CMUX System Identifier, 1)

- System 2 MUXs = COUNTIF(CMUX System Identifier, 2)

229. Therefore, the number of Large CMUX systems (System 1) is determined by summing the total number of fully utilised large systems and adding the number of System 1 CMUXs required to serve the remaining demand.

230. System 2 CMUXs are only used to accommodate remaining demand, so the number of System2 CMUXs is simply the total number of all System 2 CMUXs (i.e. where the CMUX System Identifier is equal to 2).

231. The Number of Max CMUX Systems is calculated as IF(AND(Cable Gauge Indicator= "F", Demand Served at CCP > 0), IF(Additional Fibre Cable Demand > Max_CMUX, ROUNDDOWN(Additional Fibre Cable Demand / Max_CMUX, 0), 0), 0). Therefore, if the level of demand for fibre at the CCP (i.e. pillar, building terminal or cabinet) is greater than the maximum level of demand that can be accommodated by the largest, System 1, CMUX (i.e. 786 services * fill factor) then the number of full System 1 MUXs is equal to the level of fibre demand at the CCP divided by the maximum number of services that can be accommodated on the System 1 MUX. If there is no demand at the pillar or if the type of cable is not fibre then the number of full System 1 MUXs is zero. Also, if the demand for fibre at the pillar is less than the maximum capacity of a System 1 MUX then the number of full System 1 MUXs is set to zero.

232. CMUX System Identifier is calculated as follows: IF(AND(Cable Gauge Indicator = "F", Demand Served at CCP > 0), INDEX(CMUX_System_Range, MATCH(Additional Fibre Cable Demand - Number of Max CMUX Systems * Max_CMUX, SystemCapacityRange, -1)), 0). If the type of cable modelled is fibre and there is demand at the pillar then the CMUX System Identifier is chosen from the range of systems based on the level of demand to be served. The level of demand to be served is calculated as the difference between the total level of demand at the pillar and the level of demand that is accommodated on fully utilised large CMUXs.

C.7.2 Office Units

233. In addition to the field units there are CMUX office units required for the other end of the fibre. The Number of Office CMUXs required is calculated as IF(SUM(System 1 MUXs, System 2 MUXs) = 0, 0, ROUNDUP(SUM(System 1 MUXs, System 2 MUXs) / NumberSystemsPerNU, 0)). Therefore, the number of office units required is equal to the number of System 1 and 2 field units required divided by the number of field systems that can be accommodated by each central office system (i.e. 7). In other words one central office system is required for every 7 field systems.

C.8 Number of Pairs Terminating at ESA

234. The number of pairs terminating at the ESA is calculated separately for normal copper cables, heavy copper cables and fibre cables using the following formulas:

- **Normal copper cable** = SUMIF(Next Structure Number, INDEX(Next Structure Number, MATCH(MAX(Cumulative .40 Gauge Cable Demand Segment),Cumulative .40 Gauge Cable Demand Segment)), Cumulative .40 Gauge Cable Demand Segment)

- **Heavy copper cable** = SUMIF(Next Structure Number, INDEX(Next Structure Number, MATCH(MAX(Cumulative .40 Gauge Cable Demand Segment),Cumulative .40 Gauge Cable Demand Segment)), Cumulative .64 Gauge Cable Demand Segment)

- **Fibre cable** = SUMIF(Next Structure Number, INDEX(Next Structure Number, MATCH(MAX(Cumulative .40 Gauge Cable Demand Segment),Cumulative .40 Gauge Cable Demand Segment)), Fibre Cable Size (strands))

235. The above equations are virtually identical for each of the cable types except that the columns being referenced vary by cable type. The equations identify the cable segment(s) that has the largest demand (.40 Gauge Cable Demand is where demand is the greatest), and sums the demand on those segments by cable type to identify the number of pairs entering the central office. Since main cables reach their greatest capacity as they enter the office this equation identifies the size of cables at that point.

C.9   Number of Building Terminals Served by Main Cable

236. The number of building terminals served by main cable is differentiated in the model by the size of the building terminal. Building terminal size can take one of four values: 100 pair, 50 pair, 30 pair and 10 pair.

237. The Number of 100 Pair Building Terminals is calculated as SUM(Large Terminals at Capacity) + COUNTIF(Terminal Size, x). Therefore, the number of 100 pair building terminals is equal to the sum of all large (i.e. 100 pair) terminals at full capacity plus the number of 100 pair building terminals required to accommodate remaining demand.

238. The number of other, smaller, size building terminals is calculated using the following formula:

- COUNTIF(Terminal Size, x).

239. Building terminals of a size less than 100 pairs are used to serve demand remaining after the large terminals are at full capacity or if demand is insufficient to fully utilise a large terminal. Therefore, the number of these building terminals required is simply equal to the number of building terminals of each size required to meet remaining demand.

240. Large Terminals at Capacity is calculated as IF(Building Terminal Flag > 0, ROUNDDOWN(Demand Served by CCP / BuildingTerminalMaxSize, 0), 0). Therefore, the number of large (i.e. 100 pair) terminals at full capacity is calculated as the level of demand served by the pillar divided by the maximum building terminal size. This is rounded down to return the number of full terminals only. If the main cable is not connected to a building terminal then the number of large terminals at capacity is set to zero.

241. Terminal Size is calculated as IF(Remaining Terminal Demand Requirement > 0, INDEX(BuildingTerminalSizeRange, MATCH(Remaining Terminal Demand Requirement, BuildingTerminalSizeRange, -1)), 0). If there is demand remaining (i.e. if terminals at full capacity do not serve all demand) then the terminal size to serve that remaining demand is selected based on the smallest terminal size that can accommodate the remaining demand.

242. Remaining Terminal Demand Requirement is calculated as IF(Building Terminal Flag > 0, Demand Served by CCP - Large Terminals at Capacity * BuildingTerminalMaxSize, 0). The remaining terminal demand requirement is calculated as the difference between the total demand served by the pillar and the demand served by terminals at full capacity. If the main cable is not connected to a building terminal then the remaining terminal demand is set to zero.

D   Cost Calculation Module

243. The Cost Calculation Module brings together all of the elements required to calculate the total annual costs of the efficient access network and the ULLS. This is done through the following steps.

- First, the Cost Calculation Module takes the summary output of the two engineering modules, which is the volume of labour, plant and equipment required to deploy the efficient access network, and applies the input costs and ratios to these volumes to calculate the total direct investment cost of the efficient access network. The methodology used to do this is described in detail in section D.2.

- Second, the Cost Calculation Module converts the total direct investment cost of the efficient access network into an annual capital cost by calculating both the return of and return on capital. The methodology used to undertake this conversion is set out in section D.3.

- Third, the Cost Calculation Module calculates O&M expenses and indirect capital costs. Direct O&M expenses and indirect investment costs are calculated by applying the direct O&M and indirect capital input factors to the direct investment cost. Indirect O&M expenses are calculated by applying the indirect O&M factors to the direct O&M expenses. The indirect investment cost is converted to an annual capital cost by calculating depreciation and the return on capital using the same methodology as for direct capital costs (see section D.4.1). Each of the annual cost elements is then summed to arrive at a total annual cost of the efficient access network. The methodology used for this calculation is explained in section D.4.

D.1   Description of Worksheets

244. There are twelve worksheets in the Cost Calculation module. These worksheets can be divided into the following seven categories:

- Input worksheets;

- Composite cost calculation worksheets;

- Network quantity worksheets;

- Network cost worksheets;

- Capital Cost Calculation; and

- Investment and Annual Cost Summaries.

245. Each of these categories of worksheets perform specific functions that allow the module to transform the quantities calculated in the Engineering Distribution and Engineering Main modules into investment and annual costs. Each category of worksheet is discussed below.

D.1.1   Input Worksheets

246. There are three input worksheets in the Cost Calculation Module. Each worksheet is designed to accommodate certain sets of similar inputs. The majority of inputs are user

adjustable. However, adjustments to these inputs should be made through the user interface. Changes made through the user interface will be populated into these worksheets once a specific scenario is run. Changes which are made directly into the input sheets in the Cost Calculation Module will be overridden with the data in the user interface once the integrated model is run. The three input worksheets are:

- Inputs Cost and Rules;

- Inputs Ratios; and

- Inputs Capital Costs.

D.1.1.1   Inputs Costs and Rules

247. The Inputs Costs and Rules worksheet contains all the costs for the various network components required to provide the ULLS. Most of these costs are taken directly from the "Access Network Modelling Costing Information" document that was assembled by the Telstra engineering department. There are more than 200 network cost inputs in this worksheet and they fall into the following general categories:

- Costs for main and distribution copper and fibre cables which include the cost for the cable, the costs for hauling cables through conduit and the costs for joining the cables;

- Costs for constructing pits and manholes;

- Costs for pillars including the pillar strips;

- Breakout and reinstatement costs incurred when constructing pits, manholes and conduit runs;

- Costs for buying and placing conduit in different terrains;

- Costs for terminating all the distribution facilities in the central office including the entrance facilities, cable pressurisation systems and cable terminating racks and blocks; and

- Costs for building terminals and two pair lead-ins.

248. The Inputs Costs and Rules also include inputs which represent network rules or placement and cost estimates. The estimates include the level of capitalised overheads, the amount of conduit placed by developers in new estates, the sharing of entrance facility costs between the inter-exchange and distribution network, the size of conduit trenches and the size of manholes and pits. These estimates are based on Telstra's actual costs, actual sharing experiences and actual network dimensions. There are also a number of capacity and fill factor inputs which are derived from the Dimensioning Rules Document.

D.1.1.2   Inputs Ratios

249. The Inputs Ratios identifies ratios which reflect the probable occurrence of various types of placement activities when building a new network. In deploying a new network, a company would face various types of environments where facilities would need to be constructed. In dense central business districts almost all placement of conduit and manholes would occur in areas with existing concrete or pavement. In rural areas, the probability that the trenching or constructing activity would require

dealing with concrete or pavements is significantly less. The ratios in the ratio input sheet are designed to reflect the actual environment in which this new construction would occur. The ratios in this worksheet fall into the following categories:

- Ratios for determining the type and thickness of concrete that would be encountered in building facilities in different areas;

- Ratios for identifying the portion of time each type of the breakout and reinstatement activity would be encountered when placing pits and manholes in different areas;

- Ratios for identifying the portion of time each type of breakout and reinstatement activity would be encountered when placing conduit in different areas; and

- Ratios for identifying the type of trenching or ploughing activity that would be reuired when placing conduit.

250. In determining the types of placement activities that would be encountered in placing a new network, the model needs to be able to differentiate between different areas. It is clear that the amount of concrete footpaths and roads that would be encountered varies based on the density of the area being served. For this reason the ratios for placing pits, manholes and conduit in distribution areas are segregated into five density zones. A sixth density zone is included in the model for potential use in the future. By providing separate inputs for serving areas with significantly different characteristics, the model is better suited to reflect what actually exists in the real world.

251. The model also provides separate ratios for different sizes of main conduit configurations. Again separate ratios are identified for conduit runs within a CBD and in other urban areas. In addition, the ratios can be changed based on the size of the conduit configuration. Exchange buildings are located in the densely populated areas of an exchange. Main conduit runs are small on the fringes of the exchange and get larger as they accumulate demand as they approach the central office. The ratio inputs allow the user to reflect the different characteristics of the service exchanges along these main conduit runs.

D.1.1.3 Inputs Capital Costs

252. The Inputs Capital Costs identifies all the inputs required to turn an investment amount into an annual cost. All the inputs for determining capital costs and the direct and indirect ratios for determining O&M expenses and indirect asset costs are identified on this worksheet. The capital cost inputs include the costs for debt and equity, the capital structure ratios, the tax rate and the depreciation lives for each of the asset categories. The sheet also includes expense factors for operating and maintenance expenses (expressed as a percentage of investment) and indirect expenses such as general administration and information technology (expressed as a percentage of direct O&M expenses). There are also two sets of indirect investment ratios for network assets and general and administrative assets which are expressed as a percentage of direct plant in service. By applying these capital and expense factors to investments, annual and monthly capital costs can be derived.

D.1.2 Composite Cost Calculation Worksheets

253. There are two cost calculator worksheets: *Cost Calculator Main* and *Cost Calculator Distribution*. On these worksheets the inputs from the Inputs Cost and Rules and the Inputs Ratios are used to derive composite costs that can be applied against the

investment quantities derived in the Engineering Distribution and the Engineering Main Modules. There are separate cost calculator worksheets for main and distribution costs. Functions performed on these worksheets include:

- Combining the various types of costs for a given activity to derive a combined cost for that activity (e.g. combining the material and hauling costs for cable to derive a combined single cost per metre);

- Applying the ratios for different types of placement activities to the cost of those activities to get a composite cost by density group (distribution) or conduit size (main) to apply to quantities;

- Applying ratios to account for the cost savings that occur when placing cable in developer supplied trenches and when sharing trenches between the main cable and inter exchange network facilities; and

- Applying factors to account for normal overhead loadings.

D.1.3 Network Quantity Worksheets

254. There are two network quantity worksheets: *Results Distribution – Qtys* and *Results Main – Qtys*. Each of these worksheets displays the output by exchange that is produced by the Engineering Distribution Module and the Engineering Main Module, respectively. There is one line of data for each exchange and that one line of data coincides with the single line of data that would be shown on the *Distribution – Summary* and *Main – Summary* worksheets when any single exchange is processed through the two modules[33]. The data from the Engineering Modules is simply imported into these worksheets.

D.1.4 Network Cost Worksheets

255. There are two network cost worksheets: *Results Main –Costs* and *Results Distribution - Costs*. In each of these worksheets the cost by exchange for each type of plant identified on the network quantity worksheets is calculated by applying the costs developed in the cost calculator worksheets to the quantities in the network quantity worksheets.

D.1.5 Capital Cost Calculation

256. The capital cost worksheets develop composite capital cost factors for each category of plant used in the model. These factors account for the cost of financing throughout the plant's life (i.e. equity and debt), the annual depreciation accruals throughout the life of the plant for each plant category and the taxes associated with the equity return component of capital costs. These are all combined into a single factor for each category of plant that can be applied to the investment levels developed on the other worksheets.

D.1.6 Investment and Annual Cost Summaries

257. There are two summary worksheets. The *Investment Summary* worksheet accumulates all the investment costs on the two network cost worksheets by category and divides

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[33] Note that when running numerous exchanges through the model, information for any one exchange is overwritten when the next exchange is processed.

by the number of customers in the exchange. This produces an investment cost per customer for each category of plant in the model (e.g. copper and fibre cables).

258. The annual costs for the investment derived above are calculated on the *Annual Cost Summary* worksheet. First the capital costs factors developed in the *Capital Cost Calculation* worksheet are applied to each of the investments for the various plant categories identified in the *Investment Summary* worksheet. Next the direct and indirect expense amounts are calculated by asset category. Finally, indirect asset costs are derived by asset category. These various costs are then combined to identify the annual and monthly costs associated with providing the ULLS.

259. The calculations performed by each of these worksheets and how they produce the final results, is described in more detail below.

D.2   Calculating Total Direct Investment Costs

260. Direct investment costs by exchange are calculated in the worksheets *Results Distribution – Costs* and *Results Main – Costs*. In both of these worksheets, investment costs are calculated as the volume of plant and equipment multiplied by the relevant fully loaded cost. For example, the first calculation undertaken in the *Results Distribution – Costs* worksheet is for the investment cost of 100 pair copper cable. This is calculated as the number of metres of 100 pair copper cable multiplied by the fully loaded per metre cost of 100 pair copper cable. The fully loaded per metre cost for 100 pair copper cables is derived on the Cost Calculator Distribution tab. These calculations are undertaken for each ESA selected in the model run and these results are summed across all ESAs and presented at the beginning of the *Results Distribution – Costs* and *Results Main – Costs* worksheets.

261. The volume of plant and equipment for the Distribution and Main networks are summarised in the Cost Calculation Module in the worksheets *Results Distribution – Qtys* and *Results Main – Qtys*. As discussed above, these worksheets are taken directly from the summary worksheets of the engineering modules.

262. The fully loaded costs are taken from the *Cost Calculator – Distribution* and *Cost Calculator – Main* worksheets of the Cost Calculation Module. The fully loaded costs are the sum of all material and placement costs plus a loading for indirect overheads. For example, for copper cable the fully loaded cost is the sum of the cost of the copper cable, the hauling cost and the overhead cost. For conduit, the fully loaded cost is the sum of the conduit cost, the breakout and reinstatement costs and the indirect overheads. The per unit material and placements costs and the loading factor for indirect overheads are all inputs to the model and are presented in the *Input Cost and Rules* worksheet of the Cost Calculation Module.

263. In some cases, the fully loaded costs are calculated as weighted average costs (or composite costs) across different placement activities and density zones. These weights are inputs to the model and are presented in the *Input Ratios* worksheet of the Cost Calculation Module.

264. The investment costs are summarised in the *Investment Summary* worksheet of the Cost Calculation Module on a per service basis. Main investment costs are divided by the total number of lines, including fibre main cable. This is to ensure that the costs of the main network are allocated equally between all lines in the main network, regardless of whether they are copper (and hence can be used to supply ULLS) or fibre. Distribution investment costs are divided by the total number of distribution lines.

D.3 Converting Investment Costs to Annual Capital Costs

265. In order for access prices to be sustainable, regulation must allow the capital investment costs associated with the provision of the network services to be fully recovered on an equitable basis. Recognising this, the ACCC's pricing principles for telecommunications define TSLRIC as including the cost of efficient forward-looking investment in long-lived assets required to produce network services, even if some or all of the investment will become sunk once in place[34].

266. For the purposes of calculating TSLRIC for a particular year or years, capital investment costs must be converted to annual capital costs. This is done by calculating both the return of the capital that has been invested (depreciation) and the return on that capital, which reflects the opportunity cost of that investment taking account of its risk (opportunity cost of capital).

267. The methodology Telstra has used to calculate annual capital costs in the TEA model can be described as a "building block" approach. This approach separately calculates depreciation and the opportunity cost of capital. Telstra then converts these annual payment streams into a levelised capital charge over the assets' lives. Telstra's methodology ensures that the sum of annual capital costs over the economic life of assets allows, in present value terms, the recovery of the original asset value and no more.

D.3.1 The Annual Capital Cost Factors

268. In order to convert capital costs to annual costs, the model calculates capital cost factors for each year of the assets' lives, which are comprised of depreciation and the opportunity cost of capital.

- Depreciation is calculated using the straight-line method, where the level of depreciation is equal in every year of the asset's life. Under the straight-line method, the depreciation rate is 1 divided by the economic life of the asset. For example, for an asset with an economic life of 5 years the depreciation rate is 20% and is applied to the full capital value of the asset to calculate depreciation for each year of the asset's life.

- The opportunity cost of capital is calculated by applying the vanilla post-tax WACC to the written down value of the asset for each year.

269. The capital cost factors are calculated for each asset category and vary over the asset's lives as the opportunity cost of capital, which is based on the written-down value of the asset, declines over time.

270. The calculation of the annual capital cost factors for each asset category in each year of the assets' lives is undertaken in the *Capital Cost Calculation* worksheet of the Cost Calculation Module. Specifically, the annual capital cost factors are as follows:

$$Factor = Depreciation + WACC * WrittenDownValue$$
$$Factor = D + WACC * (1 - t_{-1} * D)$$

271. where:

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34 ACCC 1997, Access Pricing Principles – Telecommunications, A Guide, July, p.38.

- D is the depreciation rate calculated as 1/N, where N is the economic life of the asset;

- WACC is the post-tax vanilla WACC adjusted for tax, that is, WACC = $WACC_{post-tax}$ * (1+ Tax Gross-up) where the Tax Gross-up is ($WACC_{pre-tax}$/$WACC_{post-tax}$ − 1); and

- t is the relevant year of the asset's life.

272. As discussed above, the opportunity cost of capital is calculated by applying the WACC to the written down value of the asset for each year. This is achieved in the formula above by multiplying the WACC by the proportion of the asset value remaining at the beginning of the year t.

273. For example, assume that the economic life of the asset is 5 years and that the capital cost factor is being calculated for year 3 of the asset's life. The depreciation rate will be 20% and, using the formula above, the WACC will be multiplied by 1 −2 * 20% or 1 − 0.4 = 0.6.

274. This example can be extended to calculate the full capital cost factor. Assuming that the WACC is set to 15%, the capital cost factor for year 3 of the asset's life would be 20% + 15% * 60% = 0.29. The capital cost factors for each year of the asset's life would be as follows:

Year = t	Capital cost calculation	Capital cost factor
1	20% + 15% * 1 – 0 * 20%	0.35
2	20% + 15% * 1 – 1 * 20%	0.32
3	20% + 15% * 1 – 2 * 20%	0.29
4	20% + 15% * 1 – 3 * 20%	0.26
5	20% + 15% * 1 – 4 * 20%	0.23

D.3.2 Levelisation of Annual Capital Cost Factors and Final Capital Cost Factor

275. The annual capital cost factors calculated for each year of the asset's life are levelised over the relevant asset's life. The levelised capital cost factor is calculated by taking the present value of the capital cost factors across all years of the asset's life. The calculation is done using an end of year convention to match the depreciation accruals. These calculations are undertaken in the *Capital Cost Calculation* worksheet of the Cost Calculation Module.

276. The present value of the capital cost factors at the end of the period, PV_{end}, is calculated as:

$$PV_{end} = \sum_{t=1}^{N} CCF_t * (1 + WACC_{post-tax})^{(-t)}$$

277. where:

- CCF is the capital cost factor that varies by year;

- WACC$_{post-tax}$ is the post-tax WACC;

- t is the year of the asset's life; and

- N is the economic life of the asset.

278. In the model, the Excel function "NPV" is used to perform these calculations. In the example above of the 5 year asset PV$_{end}$ is 1.094. Note that the net present value for the future stream would equal 1.00 if the income tax expenses were removed from the future cost stream.

279. The sum of the present values is then converted to an annual capital cost factor that is equal in each period of the asset life and exactly returns the sum of the present values at the post-tax WACC rate of return. This calculation is done as follows:

$$CapitalCostFactor_{end} = PV_{end} / \left[(1 - (1/(1 + WACC_{post-tax})^n)) / WACC_{post-tax} \right]$$

280. In the model, the Excel function "PMT" is used to perform these calculations. In the example above of the 5 year asset CapitalCostFactor$_{end}$ is 0.302.

D.4   Total Annual Cost per Service

281. The total annual cost per ULL service is the sum of:

- annual direct capital costs

- direct O&M expenses

- annual support capital costs

- annual indirect capital costs

- indirect O&M expenses

D.4.1   Annual Direct Capital Costs

282. Direct annual capital costs are calculated by applying the final capital cost factors for each asset category (see Section D.3 above) to the direct investment cost per line (see Section D.2 above) to arrive at a direct annual capital cost per line. This calculation is done in the *Annual Cost Summary* worksheet of the Cost Calculation Module.

D.4.2   Direct O&M Expenses

283. Direct O&M expenses per line are calculated by applying the direct O&M factors for each asset category to the direct investment cost per line for each asset category. The direct O&M factors are inputs to the model and are presented in the *Inputs Capital Cost* worksheet of the Cost Calculation Module. The calculation of direct O&M expenses per line is done in the *Annual Cost Summary* worksheet of the Cost Calculation Module.

D.4.3   Annual Support Capital Costs

284. Support assets consist of network land and buildings, power systems and network management systems. Annual support capital costs are calculated by first calculating the support asset investment cost. This is done by applying the support asset factors for each asset category to the direct investment cost per line for each asset category. The support asset factors are inputs to the model and are presented in the *Inputs Capital*

Cost worksheet of the Cost Calculation Module. The annual support capital costs are then calculated by applying the relevant capital cost factors to the support asset investment cost. The capital cost factors are the same as those derived for the purpose of calculating annual direct capital costs (see Section D.4.1 above) with the exception of the capital cost factor for land. In the case of land depreciation is not relevant and hence the capital cost factor is simply the return on capital or the WACC grossed up for income tax impacts.

D.4.4   Annual Indirect Capital Costs

285. Indirect assets include general purpose land and buildings, information technology including software and other indirect assets (e.g. fleet and work equipment). As with annual support capital costs, annual indirect capital costs are calculated by first calculating the indirect asset investment costs. This is done by applying the indirect asset factors for each asset category to the direct investment cost per line for each asset category. The indirect asset factors are inputs to the model and are presented in the *Inputs Capital Cost* worksheet of the Cost Calculation Module. The annual indirect capital costs are then calculated by applying the relevant capital cost factors to the support asset investment cost. The capital cost factors are the same as those derived for the purpose of calculating annual direct capital costs (see Section D.4.1 above) with the exception of the capital cost factor for land and intangibles. In these cases depreciation is not relevant and hence the capital cost factor is simply the return on capital or the WACC grossed up for income taxes.

D.4.5   Indirect O&M Expenses

286. Indirect expenses include information technology costs, product costs, accommodation and property costs and general and administrative costs. Indirect O&M expenses are calculated by applying the indirect O&M factors to direct O&M expenses for each asset category. Indirect O&M factors are inputs to the model and are presented in the *Inputs Capital Cost* worksheet of the Cost Calculation Module. The calculation of indirect O&M expenses per line is done in the *Annual Cost Summary* worksheet of the Cost Calculation Module.

287. The sum of all these costs is then combined to derive the annual cost of providing the ULL service. Dividing this amount by twelve provides the monthly cost for providing the service for all exchanges being studied. Both these amounts are identified in the *Annual Cost Summary* worksheet.

Attachment 1   Index for Engineering Distribution Module

288. The tables below provide cross-references between this document and the Excel workbook that contains the Engineering Distribution Module.

289. Table 1 provides an index for all values in the Engineering Distribution Module that are calculated (ie the result of a formula).   The first column of the table provides the name of the calculated values, which are listed in alphabetical order. The second column provides the paragraph number within this document that explains how the calculated value was derived. The third and fourth columns identify the name of the worksheet and the column reference within which the calculation is undertaken within the Excel workbook for the Engineering Distribution Module.

290. Table 2 provides an index for all base data used in the Engineering Distribution Module. The first column of the table provides the names of the base data values in alphabetical order. The second and third columns identify the name of the worksheet and the column reference where this base data can be located within the Excel workbook for the Engineering Distribution Module.

291. Table 3 provides an index for all input values used in the Engineering Distribution Module. The first column of the table provides the names of the input values in alphabetical order. The second and third columns identify the name of the worksheet and the cell reference where the input values can be located within the Excel workbook for the Engineering Distribution Module.

Table 1: Index for calculated values

Calculated Values	Paragraph	Worksheet	Column
2 Pair Lead-in Key	33	Detail	Z
10 Pair Building Terminals	119	Summary	BY
30 Pair Building Terminals	119	Summary	BX
50 Pair Building Terminals	119	Summary	BW
100 Pair Building Terminals	115	Summary	BV
Branches Coming from Dependent Pits	99	Detail	AI
Building Terminal Key	82	Detail	AU
Building Terminals Not Served by #9 & #6 Pits	110	Collapsed	G
Building Terminals Served by Pits at Route Mergers	112	Detail	AR
Cable Joints for Mergers, Cable Size Changes and Distance Limits (2 pair Cable)	51	Summary	L
Cable Joints for Mergers, Cable Size Changes and Distance Limits (10 pair Cable)	49	Summary	K
Cable Joints for Mergers, Cable Size Changes and Distance Limits (30 pair Cable)	49	Summary	J
Cable Joints for Mergers, Cable Size Changes and Distance Limits (50 pair Cable)	49	Summary	I
Cable Joints for Mergers, Cable Size Changes and Distance Limits (100 pair Cable)	49	Summary	H
Cable Length for 2 Pair Lead-ins	130	Summary	CE
Capacity Requirement at Structure	43	Detail	L
Conduit Configuration Key	97	Detail	AV
Conduit Runs 1 50mm	96	Collapsed	AA
Conduits Runs 1 100mm	95	Collapsed	Z
Conduits Runs 2 100mm	94	Collapsed	Y
Conduits Runs 4 100mm	93	Collapsed	X
Conduits Runs 6 100mm	92	Collapsed	W
Conduits Runs 8 100mm	91	Collapsed	V

Calculated Values	Paragraph	Worksheet	Column
Copper Cable Length	30	Detail	N
Copper Cable Size Index #	45	Detail	Q
Count of 2 Pair Lead-ins	127	Summary	CD
Cumulative Capacity Requirement Segment	39	Detail	M
Cumulative Distance From Last Joint	63	Detail	AM
Density	90	Collapsed	T
Density Index	89	Collapsed	U
Distance Joints Fully Utilised Cables	61	Detail	AO
Distance Joints Not Fully Utilised Cables	62	Detail	AN
Distribution Remaining Capacity Requirement	71	Collapsed	O
Fully Utilised 100 Pair Building Terminals	116	Detail	S
Fully Utilised 100 Pair Copper Cables	37	Detail	O
Fully Utilised 100 Pair Lead-ins	123	Detail	W
Fully Utilised 1800 Pillars	67	Collapsed	M
Fully Utilised Cables Requiring Distance Joints	52	Summary	N
Joined Pairs Cable Route Mergers	53	Detail	AL
Joined Pairs Cable Size Change	57	Detail	AK
Joined Pairs Service Mergers	54	Detail	AD
Large Pillars	66	Summary	O
Leadins Coming to Structure	32	Detail	AJ
Lead-ins Served by #9 and #6 Pits	109	Collapsed	F
Lead-ins Served by Pits at Route Mergers	111	Detail	AQ
Length of 10 Pair Building Terminal Lead-ins	122	Summary	CC
Length of 100 Pair Building Terminal Lead-ins	121	Summary	BZ
Length of 2 Pair Lead-ins	131	Detail	AA
Length of 30 Pair Building Terminal Lead-ins	122	Summary	CB
Length of 50 Pair Building Terminal Lead-ins	122	Summary	CA
Length of Building Terminal Lead-ins	125	Detail	X
Length of Distribution Conduit Runs in Density Range 1-Metres			
Size of Conduit Configuration:			
8	86	Summary	T
6	86	Summary	U
4	86	Summary	V
2	86	Summary	W
1	86	Summary	X
0.5	86	Summary	Y
Length of Distribution Conduit Runs in Density Range 2-Metres			
Size of Conduit Configuration:			
8	86	Summary	Z
6	86	Summary	AA
4	86	Summary	AB
2	86	Summary	AC
1	86	Summary	AD
0.5	86	Summary	AE
Length of Distribution Conduit Runs in Density Range 3-Metres			
Size of Conduit Configuration:			
8	86	Summary	AF
6	86	Summary	AG
4	86	Summary	AH
2	86	Summary	AI
1	86	Summary	AJ
0.5	86	Summary	AK
Length of Distribution Conduit Runs in Density Range 4-Metres			
Size of Conduit Configuration:			
8	86	Summary	AL
6	86	Summary	AM
4	86	Summary	AN
2	86	Summary	AO
1	86	Summary	AP
0.5	86	Summary	AQ

Calculated Values	Paragraph	Worksheet	Column
Length of Distribution Conduit Runs in Density Range 5-Metres			
Size of Conduit Configuration:			
8	86	Summary	AR
6	86	Summary	AS
4	86	Summary	AT
2	86	Summary	AU
1	86	Summary	AV
0.5	86	Summary	AW
Length of Distribution Conduit Runs in Density Range 6-Metres			
Size of Conduit Configuration:			
8	86	Summary	AX
6	86	Summary	AY
4	86	Summary	AZ
2	86	Summary	BA
1	86	Summary	BB
0.5	86	Summary	BB
Main Remaining Capacity Requirement	70	Collapsed	N
Non Commercial Addresses	81	Collapsed	E
Number of 2 Pair Lead-ins	128	Detail	AC
Number of Cable Joints on Pillar	64	Summary	M
Number of Cables in Segment	74	Detail	AF
Number of Distribution Cables Connected to Pillar	72	Collapsed	Q
Number of Large Terminal Strips	76	Summary	Q
Number of No. 5 Pits Required	106	Collapsed	J
Number of No. 6 Pits Required	105	Collapsed	I
Number of No. 9 Pits Required	104	Collapsed	H
Number of Pairs	129	Detail	AB
Number of Pits in Density Range 1:			
No. 9	101	Summary	BD
No. 6	101	Summary	BE
No. 5	101	Summary	BF
Number of Pits in Density Range 2:			
No. 9	101	Summary	BG
No. 6	101	Summary	BH
No. 5	101	Summary	BI
Number of Pits in Density Range 3:			
No. 9	101	Summary	BJ
No. 6	101	Summary	BK
No. 5	101	Summary	BL
Number of Pits in Density Range 4:			
No. 9	101	Summary	BM
No. 6	101	Summary	BN
No. 5	101	Summary	BO
Number of Pits in Density Range 5:			
No. 9	101	Summary	BP
No. 6	101	Summary	BQ
No. 5	101	Summary	BR
Number of Pits in Density Range 6:			
No. 9	101	Summary	BS
No. 6	101	Summary	BT
No. 5	101	Summary	BU
Number of Small Terminal Strips	76	Summary	R
Number to Identify Next Structure	42	Detail	AW
Pairs Terminated Main Side Pillar	69	Collapsed	K
Pillar Key	73	Detail	AT
Pit Extensions Required	79	Summary	S
Pit Extensions Required	80	Collapsed	S
Pit Sizing Key	107	Detail	AS
Pits at Route Merges and Distance Limits	108	Detail	AP
Remaining Capacity Requirement	46	Detail	P

Calculated Values	Paragraph	Worksheet	Column
Remaining Terminal Demand	118	Detail	T
Size Cable to Serve Remaining Demand	44	Detail	R
Size Lead-in Cable to Serve Remaining Demand	124	Detail	Y
Size of Cables	55	Detail	AE
Size of Conduit Required	98	Detail	AG
Size of Required Terminal	117	Detail	U
Small Pillars	75	Summary	P
Structure Key	35	Detail	V
Structure Type	34	Detail	AH
Terminal Strips Needed	77	Collapsed	R
Total Length of Distribution Cables of 10 pairs	29	Summary	G
Total Length of Distribution Cables of 100 pairs	28	Summary	D
Total Length of Distribution Cables of 30 pairs	29	Summary	F
Total Length of Distribution Cables of 50 pairs	29	Summary	E
Type of Pillar Required	68	Collapsed	P

Table 2: Index for base data

Base Data	Worksheet	Column
Area (sq. km)	Collapsed	D
Building Terminal	Detail	G
Building Terminal Size	Detail	H
Current Structure Number	Detail	I
DA #	Collapsed	B
DA #	Detail	B
Demand Served by Pillar	Collapsed	C
Lead-ins Served by Structure	Detail	E
Next Structure Number	Detail	J
Segment Length	Detail	C
Total Distance to the Pillar	Detail	D
Trace Level	Detail	K
Type of Structure	Detail	F

Table 3: Index for input values

Input Values	Worksheet	Cell
AverageLargeLeadInLength	Input	D108
AverageSmallLeadInLength	Input	D107
ConduitConfigurationRange	Input	B83-88
ConduitConfigurationSizeRange	Input	C98-88
DensityRange	Input	C24-29
DistributionCopperCableFill	Input	A15
DistributionCopperCableLengthRange	Input	B41-44
DistributionCopperCableSizeRange	Input	A41-44
DistributionMaxCopperCableLength	Input	B41
DistributionMaxCopperCableSize	Input	A41
FeederFill	Input	A17
LeadInMaxSize	Input	A95
LeadInSizeRange	Input	A95-98
MaxPillarCapacity	Input	C77
MaxPillarSize	Input	B77
MaxServingPitCable	Input	A49
MinLeadIn	Input	B103
MinPillarCapacity	Input	C78
MinPillarSize	Input	B78
NonTaperMaxCopperCableLength	Input	B36
PitSpacingRange	Input	B60-62
ServingPitCableRange	Input	A49-53

Input Values	Worksheet	Cell
StudySelection	Input	A126
TaperSelection	Input	A11
TerminalStripSizingRange	Input	D77-78
WeightedLeadinsPerPit	Input	C71

Attachment 2   Index for Engineering Main Module

292.   The tables below provide cross-references between this document and the Excel workbook that contains the Engineering Main Module.

293.   Table 4 provides an index for all values in the Engineering Main Module that are calculated (ie the result of a formula).   The first column of the table provides the name of the calculated values, which are listed in alphabetical order. The second column provides the paragraph number within this document that explains how the calculated value was derived. The third and fourth columns identify the name of the worksheet and the column reference within which the calculation is undertaken within the Excel workbook for the Engineering Main Module.

294.   Table 5 provides an index for all base data used in the Engineering Main Module. The first column of the table provides the names of the base data values in alphabetical order. The second and third columns identify the name of the worksheet and the column reference where this base data can be located within the Excel workbook for the Engineering Main Module.

295.   Table 6 provides an index for all input values used in the Engineering Main Module. The first column of the table provides the names of the input values in alphabetical order. The second and third columns identify the name of the worksheet and the cell reference where the input values can be located within the Excel workbook for the Engineering Main Module.

Table 4: Index for calculated values

Calculated Values	Paragraph	Worksheet	Column
.40 Gauge Cable at Mergers	207	Collapsed	S
.40 Gauge Cable Joint at Mergers	219	Collapsed	AC
.40 Gauge Cable Joint at Pillar	221	Collapsed	AF
.40 Gauge Cable Segment Demand	168	Detail	V
.40 Gauge Distance Joints Less Than Full Cables	224	Collapsed	AI
.40 Gauge Large Main Cable	158	Summary	P
.64 Gauge Cable Segment Demand	172	Detail	W
.64 Gauge Cable at Mergers	208	Collapsed	T
.64 Gauge Cable Joint at Mergers	220	Collapsed	AD
.64 Gauge Cable Joint at Pillar	222	Collapsed	AG
.64 Gauge Distance Joints Less Than Full Cables	225	Collapsed	AJ
.64 Gauge Large Main Cable	158	Summary	E
Additional .40 Gauge Cable Demand	181	Detail	S
Additional .64 Gauge Cable Demand	182	Detail	T
Additional Capacity Requirement	183	Detail	P
Additional Fibre Cable Demand	151	Detail	U
Branch Kits for Fibre Cable	226	Summary	BE
Branch Kits for Heavy Copper Cable	226	Summary	AW
Branch Kits for Normal Copper Cable	226	Summary	AQ
Branches Feeding Current Structure	206	Collapsed	R
Building Terminal Flag	148	Detail	Y
Cable Gauge Indicator	146	Detail	R
CMUX System Identifier	232	Detail	AD
Cumulative .40 Gauge Cable Demand Segment	164	Collapsed	E
Cumulative .64 Gauge Cable Demand Segment	165	Collapsed	F
Cumulative Fibre Cable Demand Segment	209	Collapsed	G
Demand at Fibre Fed Pillars	145	Summary	D
Distance From Last Manhole	214	Collapsed	Y
Distance Manholes	213	Collapsed	Z
Fibre Cable at Mergers	208	Collapsed	U
Fibre Cable Joint at Pillar	222	Collapsed	AH

Calculated Values	Paragraph	Worksheet	Column
Fibre Cable Joints at Mergers	220	Collapsed	AE
Fibre Cable Segment Demand	176	Detail	X
Fibre Cable Size (strands)	196	Collapsed	N
Fibre Distance Joints for Less Than Full Cable	225	Collapsed	AK
Fibre Large Main Cable	158	Summary	K
Fully Utilised Large Copper Cables (.40 Gauge)	161	Collapsed	I
Fully Utilised Large Copper Cables (.64 Gauge)	162	Collapsed	J
Fully Utilised Large Fibre Cables	163	Collapsed	K
Heavy Cable Size (pairs)	196	Collapsed	M
Heavy Gauge Cable Requirement	188	Detail	O
Large Terminals at Capacity	240	Detail	Z
Length of Main Conduit			
Conduit Configuration:			
24	197	Summary	W
20	197	Summary	X
16	197	Summary	Y
12	197	Summary	Z
8	197	Summary	AA
6	197	Summary	AB
4	197	Summary	AC
2	197	Summary	AD
1	197	Summary	AE
Length of .40 Gauge Main Cables			
Cable Size:			
1200	191	Summary	F
800	191	Summary	G
400	191	Summary	H
200	191	Summary	I
100	191	Summary	J
Length of .64 Gauge Main Cable			
Cable Size:			
800	191	Summary	L
400	191	Summary	M
200	191	Summary	N
100	191	Summary	O
Length of Fibre Main Cable			
Cable Size:			
60	193	Summary	Q
48	193	Summary	R
36	193	Summary	S
24	193	Summary	T
12	193	Summary	U
6	193	Summary	V
Lookup Key	167	Detail	L
Manhole Key	210	Collapsed	Q
Manhole Size (Distance)	211	Collapsed	AB
Manhole Size (Mergers)	203	Collapsed	X
Manhole Sizing Index (Distance)	212	Collapsed	AA
Manhole Sizing Index (Mergers)	205	Collapsed	W
Manholes at Cable Mergers	204	Collapsed	V
Normal Cable Size (pairs)	195	Collapsed	L
Number of 10 Pair Building Terminals	238	Summary	BO
Number of 30 Pair Building Terminals	238	Summary	BN
Number of 50 Pair Building Terminals	238	Summary	BM
Number of 100 Pair Building Terminals	237	Summary	BL
Number of Cables in Section	200	Collapsed	O
Number of Conduits Required	199	Collapsed	P
Number of Fibre Strands	166	Collapsed	H
Number of Fibres	184	Detail	AE
Number of Joints Fibre Cable			

Calculated Values	Paragraph	Worksheet	Column
Size of Cable:			
120	215	Summary	AX
60	216	Summary	AY
48	216	Summary	AZ
36	216	Summary	BA
24	216	Summary	BB
12	216	Summary	BC
6	216	Summary	BD
Number of Joints Heavy .64 Gauge Cable			
Size of Cable:			
1200	215	Summary	AR
800	216	Summary	AS
400	216	Summary	AT
200	216	Summary	AU
100	216	Summary	AV
Number of Joints Normal .40 Gauge Cable			
Size of Cable:			
2400	215	Summary	AK
1200	216	Summary	AL
800	216	Summary	AM
400	216	Summary	AN
200	216	Summary	AO
100	216	Summary	AP
Number of Max CMUX Systems	231	Detail	AC
Number of Office CMUXs Required	233	Summary	BH
Number of Pairs Terminating at ESA (Fibre Cable)	234	Summary	BK
Number of Pairs Terminating at ESA (Heavy Copper Cable)	234	Summary	BJ
Number of Pairs Terminating at ESA (Normal Copper Cable)	234	Summary	BI
Number of Pits and Manholes			
Size of Pit/Manhole:			
#9 Pit	201	Summary	AJ
28	201	Summary	AF
20	201	Summary	AG
12	201	Summary	AH
4	201	Summary	AI
Origination Point	179	Detail	M
Remaining Terminal Demand Requirement	242	Detail	AA
System 1 MUXs	228	Summary	BF
System 2 MUXs	228	Summary	BG
Terminal Size	241	Detail	AB
Termination Point	180	Detail	N
Total Joint .40 Gauge Cable	218	Collapsed	AL
Total Joint .64 Gauge Cable	218	Collapsed	AM
Total Joint Fibre Cable	218	Collapsed	AN
Type of Cable Modelled	149	Detail	Q

Table 5: Index for base data

Base Data	Worksheet	Column
Cable Number	Detail	C
Cross Connect Point (CCP)	Detail	D
Current Structure Number	Collapsed	C
Current Structure Number	Detail	F
Demand Served at CCP	Detail	H
Existing Type of Cable	Detail	B
Longest Cable in Serving Area (DA)	Detail	J
Next Structure Number	Collapsed	D

Base Data	Worksheet	Column
Next Structure Number	Detail	G
Scenario	Summary	C
Segment Length	Collapsed	B
Segment Length	Detail	E
Segment Number	Detail	K
Total Distance from CO	Detail	I

Table 6: Index for input values

Input Values	Worksheet	Cell
BuildingTerminalMaxSize	Inputs	A88
BuildingTerminalSizeRange	Inputs	A88-92
CMUX_System_Range	Inputs	B78-79
CMUXFibreRange	Inputs	F78-79
ConduitConfiguationRange	Inputs	B65-73
CrossoverCode	Inputs	A12
FeederFill	Inputs	A16
FibreCableLengthRange	Inputs	B45-51
FibreCableRange	Inputs	A54-51
HeavyCopperFeederCableRange	Inputs	A36-40
HeavyFeederCableLengthRange	Inputs	B36-40
ManholeSizingRange	Inputs	B56-60
ManholeSpacingRange	Inputs	C56-60
Max_CMUX	Inputs	E78
Max_Number_of_Conduits	Inputs	B65
MaxCMUXFibre	Inputs	F78
MaxFibreCable	Inputs	A45
MaxHeavyFeederCable	Inputs	A36
MaxNormalFeederCable	Inputs	A25
NormalCopperFeederCableRange	Inputs	A25-30
NormalCopperFeederLengthRange	Inputs	B25-30
StudySelection	Inputs	A11
SystemCapacityRange	Inputs	E78-79