



Development of the Danish LRAIC model for fixed networks

Excel model manual

[Version after 3rd consultation]

Axon Partners Group

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Contents

Contents	1
1. Introduction	4
2. Excel model architecture	5
3. Market and network inputs	7
3.1. Demand.....	7
3.1.1 Copper shutdown.....	9
3.2. Asset costs.....	13
3.3. Adjustment for fully depreciated assets	15
3.4. Broadband traffic	17
3.5. Demand distribution	18
3.6. Network efficiency adjustment.....	19
3.7. Non-network overheads.....	22
3.8. Ancillary services inputs.....	23
3.9. Other network and costing inputs.....	24
4. Geographical inputs.....	26
4.1. Coverage	26
4.2. Access network elements and distribution	27
4.3. Core network inputs	28
4.4. Other geographical inputs	29
5. Dimensioning module	30



5.1.	Dimensioning drivers	30
5.1.1	Dimensioning drivers' concept	31
5.1.2	Mapping services to drivers	31
5.1.3	Conversion from services to drivers	32
5.2.	Transmission network dimensioning	33
5.3.	Access Network Dimensioning	43
5.3.1	Copper Access Network Dimensioning	43
5.3.2	Fibre Access Network Dimensioning.....	54
5.3.3	Coax Access Network Dimensioning	65
6.	Resources costing	74
6.1.	Calculation of network costs	74
6.2.	Calculation of non-network costs.....	77
7.	Network costs of the services	79
7.1.	Incremental and common costs calculation	79
7.2.	Allocation of network costs to services.....	80
7.2.1	Step 1: Mapping of services and resources	81
7.2.2	Step 2. Calculation of demand for the three allocation criteria	81
7.2.3	Step 3: Cost Allocation to Services.....	82
Annex A.	User manual for the Excel model	84
A.1.	Getting started	84
A.2.	General overview of the model	84
A.2.1.	Support and control worksheets	86



A.2.2.	Step 0: Parameters.....	87
A.2.3.	Step 1: Main inputs.....	87
A.2.4.	Step 2: Advanced inputs.....	88
A.2.5.	Step 3: Mapping.....	89
A.2.6.	Step 4: Drivers and demand factors.....	90
A.2.7.	Step 5: Dimensioning of the network.....	91
A.2.8.	Step 6: Resource Costing.....	92
A.2.9.	Step 7: Allocation of costs.....	92
A.2.10.	Step 8: Results.....	93
A.2.11.	Additional support sheets.....	93
A.3.	Understanding the control panel.....	94
A.3.1.	Execution Panel.....	95
A.3.2.	Input scenarios.....	97
A.3.3.	Results overview.....	98
A.4.	Description of checks.....	99
Annex B.	Description of the ancillary services.....	101
Annex C.	List of acronyms.....	108



1. Introduction

Since 2003, the DBA has annually regulated the wholesale prices for several fixed-network services through a Long Run Average Incremental Cost (LRAIC) model. As presented in the Model Reference Paper (hereinafter, 'the MRP') from October 2019¹, the relevant changes that occurred in the fixed Danish market since the last major update of the model in 2013, merited a new update of the fixed LRAIC model (hereinafter, 'the model') to make sure it is representative of the current situation and can fulfil DBA's regulatory needs.

The model developed by DBA incorporates the feedback received from the industry in the three consultations rounds that have taken place in the context of the modelling phase of the project, throughout the year 2020. This model has been developed following the methodological principles laid out in the MRP from October 2019, which was subject to consultation with the industry between 1st July to 30th August 2019.

In the context of the main project, two different Fixed LRAIC model have been developed: One model based on TDC and one model based on Norlys (combining Eniig and SE). Each Fixed LRAIC model consists in two parts:

- ▶ **R model:** Used to perform a geographical assessment of the access and transmission networks in Denmark.
- ▶ **Excel model:** Used to calculate services' costs, following a set of inputs and calculations. In this case, while the calculations considered for both, TDC and Norlys are identical, the inputs included in the model differ, as each is based on the data that operators have been able to provide.

This document represents the Excel model manual. This manual aims to describe the modelling approach, structure and calculation process followed in the development of the Excel model. In addition, 'Annex A - User manual for the Excel model' presents a simple set of guidelines to follow when using the Excel model and 'Annex B - Description of the ancillary services', presents a description of the ancillary services included in the model.

¹ Link: <https://erhvervsstyrelsen.dk/sites/default/files/2019-10/Final%20MRP.pdf>



2. Excel model architecture

The excel model developed follows a classical Bottom-Up LRAIC architecture. The architecture of the model is divided into blocks, to ease its conceptualisation. A high-level diagram of the blocks considered in the model and their relationship is presented in the figure below.

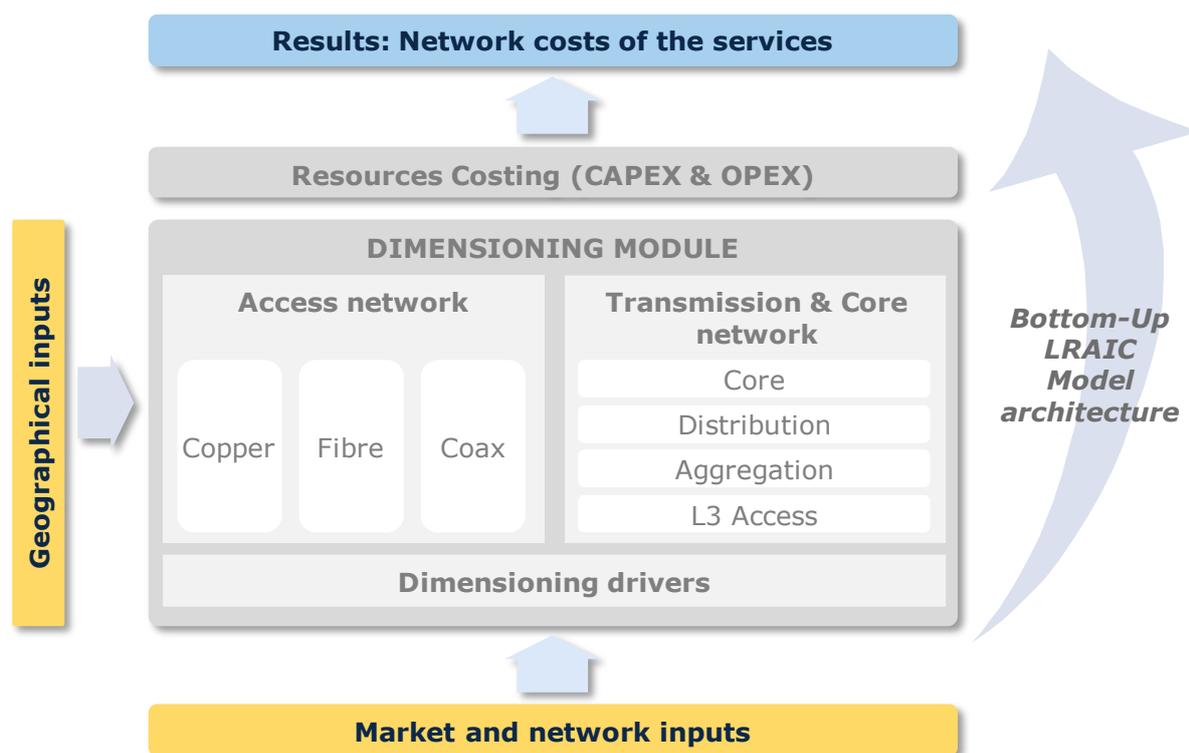


Exhibit 2.1: Structure of the model [Source: Axon]

As seen in this figure, several main function blocks are relevant to the model. These are:

- ▶ **Market and network inputs:** These inputs represent basic data from the market (e.g. demand) and network (e.g. traffic statistics) that the model uses in to perform its calculations (section '3 - Market and network inputs').
- ▶ **Geographical inputs:** Analysis of the geographical characteristics of Denmark, based on the road network, the existing building and access nodes of the operator (section '4 - Geographical inputs').



- ▶ **Dimensioning module:** Calculation of the number of resources needed for the network to supply the services provided by the reference operator (section 5 - Dimensioning module’).
- ▶ **Resources costing:** Assessment of the annualized costs of the network, in terms of operational (OpEx) and capital (CapEx) costs (section `6 - Resources costing’).
- ▶ **Network costs of the services:** Allocation of the costs of the resources to services and calculation of the final unit costs of the services considered in the model (section `7 - Network costs of the services’).

Each of these modules is presented with a high level of detail in the sections below.



3. Market and network inputs

The Excel cost model developed is data-intensive and has been populated with the information requested from the operators (through various data-gathering processes, including data reported as part of the public consultation processes), as well as additional publicly available information and other data available to DBA. Different sets of inputs have been defined for TDC and Norlys.

The model's inputs are included under the "Market and network inputs" and the "geographical analysis" blocks illustrated in Exhibit 2.1. The former is described in this section, while the latter is presented in section '4 - Geographical inputs' below.

The "Market and network inputs" block includes the following inputs:

- ▶ Demand
- ▶ Asset costs
- ▶ Adjustment for fully depreciated assets
- ▶ Broadband traffic
- ▶ Demand distribution
- ▶ Network efficiency adjustment
- ▶ Non-network overheads
- ▶ Ancillary services inputs
- ▶ Other network and costing inputs

The following sections describe how each of these inputs has been defined in the model.

3.1. Demand

The demand of the modelled services is one of the primary inputs of the cost model and is crucial to determine the required elements in some parts of the network, as well as to calculate the unit costs of the services. This input is introduced in worksheet '1A INP DEMAND' for each of the modelled services and for the whole modelling period (i.e. from 2005 to 2038).



We have adopted the approach described below to populate the demand inputs in the model:

- ▶ Whenever information was provided by the modelled operator (for past, current and future years), we mapped it to the relevant modelled services and inputted it to the model.
 - In the case of TDC, information from the modelled operator was used for 69% of all demand data points.
 - In the case of Norlys, information from the modelled operator was used for 41% of all demand data points.
- ▶ In the absence of such information, we extracted it from the previous DBA's model, provided it was available.
 - In the case of TDC, the information from DBA's previous model allowed us to fill in an additional 14% of the demand data points.
 - In the case of Norlys information from the previous DBA's model was not considered.
- ▶ Finally, when no information was available from any of the two previous sources, it was estimated based on the information available for other years² or based on other parameters (such as reported take-up).
 - In the case of TDC, the information from these regression analyses allowed us to populate the remaining 17% of the demand data points.
 - In the case of Norlys, the information based on take-up forecasts reported by the operator, allowed us to populate the remaining 59% of the demand data points. Due to the lack of data, the model considers all addresses to be "sellable".

² It should be noted that data was found for all the services for at least 4 consecutive years.



3.1.1 Copper shutdown

Modelling the copper shutdown

TDC's model includes a copper-shutdown feature. The objective of this feature is to assess the effect that a potential shutdown of the copper network in the medium term may have for the cost of providing fixed services in Denmark.

The copper shutdown feature assumes that before the last modelling year (2038), the copper network will be completely shut down, i.e. having no users and all assets being decommissioned.

The copper shutdown is performed by progressively reducing the demand in the copper network beyond the figures reported by the modelled operator.

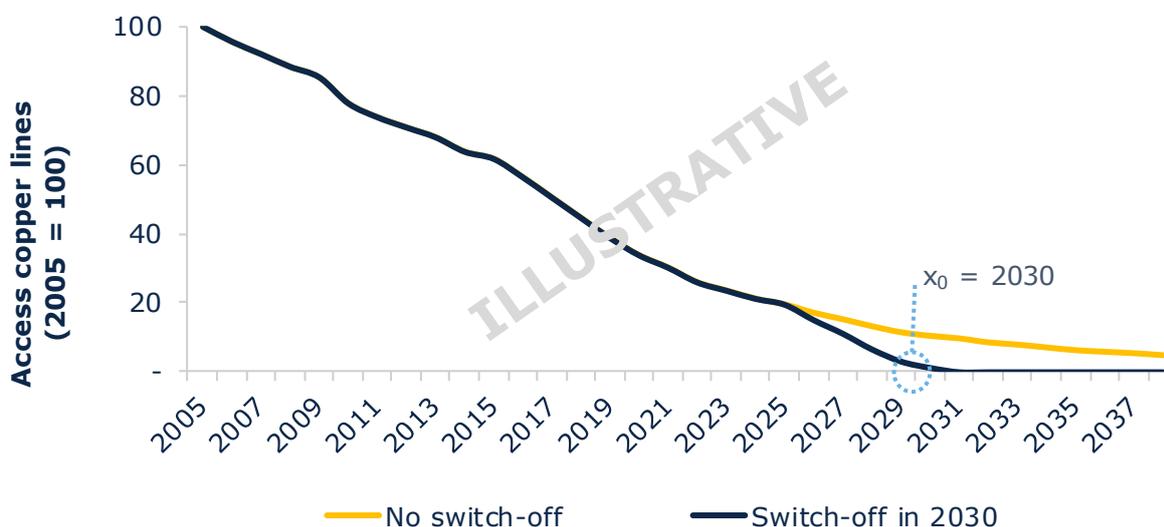


Exhibit 3.1: Illustrative example of copper shutdown in 2030 [Source: Axon]

The copper shutdown year (x_0) is an input defined in the control panel (see 'Annex A - User manual for the Excel model' for further details).

The migration pattern shown above is governed by a simple logistics curve that shuts down all copper demand over a 5-year period. The formula considered along with the shape of the pattern is presented in the exhibit below:

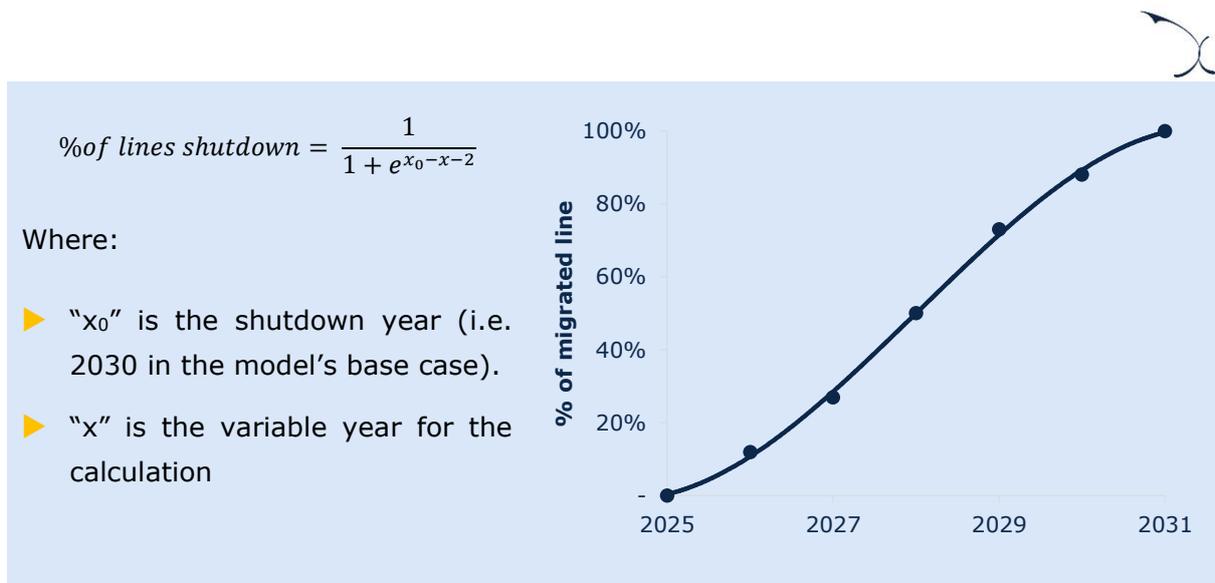


Exhibit 3.2: Migration pattern for the copper shutdown, considering 2030 as the year of shutdown
 [Source: Axon]

The lines shutdown from the copper network are not “lost” in the model. On the contrary, the model estimates whether the lines shall be migrated to other TDC’s networks (coax or fibre) or to other operators (not included in the model). In order to do so, the model looks at the different Central Offices where there remains demand for the copper network when the shutdown starts to take place³. For each of the Central Office areas, the model takes a decision:

- ▶ If the area has both, coax and fibre coverage, then the model splits the remaining copper demand between the coax and fibre evenly (50-50). The model reviews whether the fibre coverage in the area is PON or PTP to ensure the demand is allocated to the appropriate network.
- ▶ If the area has either, coax or fibre coverage but not both, then the model assigns the remaining copper demand to either coax or fibre networks (depending on which network has coverage). In this case, the model also reviews whether the fibre coverage in the area is PON or PTP to ensure the demand is allocated to the appropriate network.
- ▶ If the area does not have neither coax nor fibre coverage, then the copper demand associated to this network is considered to go to other networks that are not TDC’s fixed networks.

³ These calculations are included in worksheet ‘4A CALC COPPER SHUTDOWN’.



Annualisation of copper shutdown costs

When assessing the impact of a copper shutdown before the end of the modelling period, it is particularly important to evaluate its implications on the recovery of the capital costs.

In particular, the model calculates and annualises the investment required for copper access networks over the useful lives of the assets. At the same time, the timeframe of the model was set in line with the useful lives of these assets to guarantee a consistent approach in the depreciation of their GRC. However, if the copper network is shut down before the end of their useful lives, it becomes important to define the treatment to be given to the annualization of such costs. There are mainly two alternatives to address this issue:

- a) **All GRC is annualized within the “active” years of the copper network.** This would imply artificially adjusting the useful lives of the copper access assets to ensure they are either lower or equal to the modelling timeframe.
- b) **Only the GRC that, according to the technical useful lives of the assets, is expected to be annualized during the “active” years of the copper network is considered.** This would imply keeping the originally defined technical useful lives and consider the default annualisation costs generated by these assets in any year of the model.

Alternative a) above would naturally lead to higher unit costs for the copper access services when a copper network shutdown is expected to take place before 2038 (the last year of the model). On the other hand, if no shutdown of the copper network is expected (or if it takes place in 2038), both alternatives will lead to the same results.

Even though alternative b) could seem to lead to an under-recovery of costs by the modelled operator, it is important to clarify that this may not necessarily be the case. This is because the model considers all non-fully depreciated assets to be newly deployed in 2005, which is a common technique in Current Cost Accounting (CCA) Bottom-Up cost models but does not reflect the factual situation of the modelled operator. This implies that the NRC considered in the model in 2005 is notably higher than the Net Book Value (NBV), even if indexed, registered in the modelled operator’s financials.

As discussed in the previous section, when no copper shutdown is considered, the difference in the 2005 NRC is offset throughout the modelled period because the model



does not consider new reinvestments in the main passive copper access assets while the modelled operator does in practice (e.g. due to the yearly replacements required). This means that under this scenario, the cost base recovered in the model and the cost base expected to be recovered by the modelled operator are broadly similar.

However, if a copper shutdown is considered to take place before 2038, alternative a) may indeed lead to an over-recovery of the modelled operator's costs, as the financial NBV (even if indexed) of the modelled operator could not have enough time to reach, in practice, the 2005 NRC considered in the model.

The exhibit below provides an illustrative example of the behaviour that should be expected in the model and in the modelled operator's financials when no copper shutdown is considered and when the copper network is expected to be shut down in 2030 (under alternatives a and b):

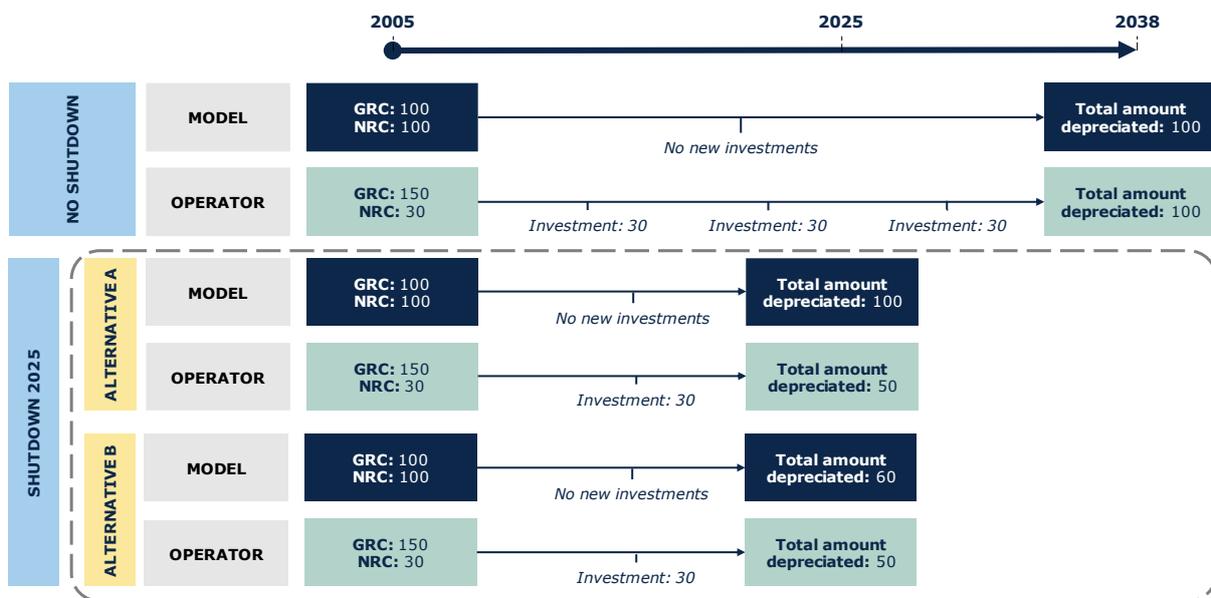


Exhibit 3.3: Illustrative behaviour of the model and the modelled operator's financials under different copper shutdown scenarios [Source: DBA]

As a base case, the model considers that the shutdown of the copper network will take place in 2030 and that the GRC is annualized within the "active" years of the copper network. Those scenarios can be modified by the user through a drop-down list included in the control panel. Further details on the scenarios and guidelines to operate the Excel model can be found in 'Annex A - User manual for the Excel model'.



3.2. Asset costs

The assets' costs and associated information are included in worksheet '1B INP UNIT COSTS' of the model for each of the network elements defined. These inputs are used to calculate the annualised operational and capital costs which are to be later allocated to services.

For each of the assets defined in the model, this worksheet includes:

- ▶ Inputs relevant to **capital expenditures**.
 - **Unit CapEx**. Includes the costs associated with the purchase and installation of the network element.
 - **CapEx trend**. Cost trends for CapEx are defined in the cost model to assess the evolution of prices over the years.
 - **Useful lives**. Useful lives are introduced in the model for the annualisation of the assets' CapEx.
- ▶ Inputs relevant to **operational expenditures**.
 - **Unit OpEx**. Includes the annual cost of maintenance and operation of the network element. It also includes rental expenses.
 - **Percentage of labour work**. Percentage of OpEx that is coming from staff costs.

As per the MRP, the prices used in the model should reflect those that an efficient operator would face, considering the scale of the modelled operator.

To populate these inputs, we have followed the approach illustrated below:

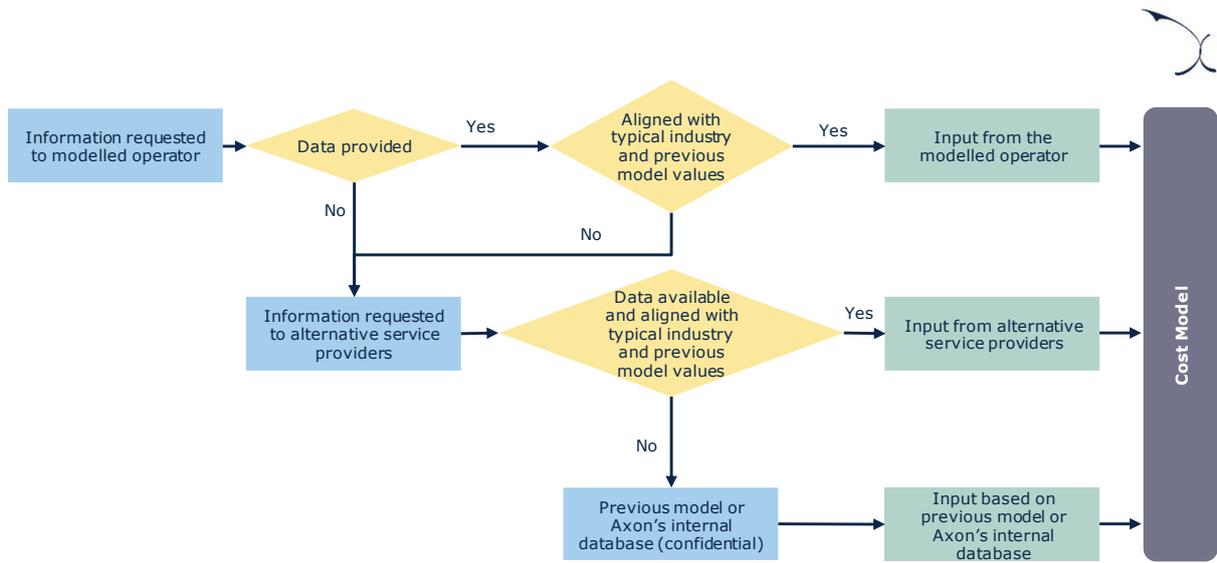


Exhibit 3.4: Decision tree adopted to define the assets' costs inputs [Source: Axon]

The table below provides a brief summary of the approach adopted for each input for each of the modelled operators:



Parameter	Input from the modelled operator	Input from alternative operator(s) ⁴	Input from existing models	Input from international benchmarks
Unit CapEx				
TDC	78% ⁵	3%	6%	13%
Norlys	65%	8%	15%	15%
CapEx trend				
TDC	1%	19%	18%	62%
Norlys	-	21%	19%	60%
Useful lives				
TDC	12%	11%	77%	-
Norlys	8%	-	92%	-
Unit OpEx				
TDC	67%	-	28%	5%
Norlys	-	14%	49%	37%
Percentage of labour costs				
TDC	100%	-	-	-
Norlys	-	73%	23%	-

Exhibit 3.5: Summary of the approaches followed to populate the unit costs inputs [Source: Axon]

3.3. Adjustment for fully depreciated assets

As presented in the MRP, the model does not take fully depreciated assets in copper and coax access networks⁶ into consideration to avoid over-recovering their costs. Particularly, this consideration applies to the following assets:

- ▶ **Copper networks:** Copper cable, including civil infrastructure used to install these cables (trenches, ducts, etc.).
- ▶ **Coax networks:** Coax cable, including civil infrastructure used to install these cables (trenches, ducts, etc.).

⁴ This category includes information extracted for official Danish agencies, as StatBank.

⁵ 56% of the inputs are directly extracted from TDC's data meanwhile the remaining 22% have been extracted based on data reported by the operator, with minor adjustments.

⁶ No adjustment is applied in the case of fibre networks



Therefore, this adjustment applies only to TDC, as no copper network have been considered so far with regards to Norlys. Note that this adjustment has been set to 0 for both TDC and Norlys

To apply this adjustment, detailed information from TDC's Fixed Asset Register (FAR) was required in terms of:

- ▶ Total gross book value (GBV) of the assets under operation in the copper and coax access networks.
- ▶ The year when the assets were originally purchased.

Note that, as explained in the MRP, the useful lives from the existing LRAIC models are considered instead of the accounting useful lives to ensure consistency with the regulation adopted by DBA so far.

However, when assessing TDC's information, three main limitations where identified:

- ▶ There is no information regarding assets that were fully depreciated by 1995. Therefore, these could not be accounted for in the calculations performed, leading to a potential underestimation of the percentage of fully depreciated assets.
- ▶ Even though the percentage of fully depreciated assets had to be calculated as of the first year of the model (i.e. 2005), the DBA-Axon team only had access to a detailed Fixed Asset Register from the modelled operator for the year 2018, meaning that the calculation of the percentage of fully depreciated assets actually refers to 2018. This could arguably lead to a potential overestimation of the percentage of fully depreciated assets.
- ▶ The usage of the regulatory useful lives could be argued, given that even though these should be preferred, they were only used for regulatory purposes since the late 2000s. This means that TDC probably recovered most of the access assets' costs beforehand, based on its financial useful lives. Therefore, the adoption of the regulatory useful lives may lead to a potential underestimation of this percentage.

Despite this situation, the table below illustrates the figures obtained from the TDC's FAR:



Parameter	Copper networks	Coax networks
Figures from the FAR		
Total GBV of the assets currently under operation	100,0	100,0
Total GBV of the fully depreciated assets	27,0	23,6
Figures from the FAR indexed to 2018, based on inflation		
Total GRC of the assets currently under operation [a]	150,6	118,7
Total GRC of the fully depreciated assets [b]	55,4	32,2
Indexed ratio of fully depreciated assets [b/a]	36,8%	27,1%

Exhibit 3.6: Figures⁷ considered for the calculation of fully depreciated assets [Source: DBA]

The aforementioned limitations drive the actual share of fully depreciated assets in opposite directions. However, we observe that two aspects would be driving the share of fully depreciated assets upwards, while one of the aspects would be driving these costs downwards. DBA considers that this imbalance may pull upwards the overall percentages calculated in the table above (36,8% and 27,1%). This outcome is also supported by the results of the confidential benchmarks available to Axon. Thus, DBA considers that, based on the lack of more accurate data, a percentage of fully depreciated assets equal to 50% is reasonable. In the case of coax networks, after discussions with the EC on the matter, this figure has been set to zero for the time being.

Based on the feedback received in the 1st consultation process, two drop-down lists have been included in the Excel model's control panel to set the percentages applicable to copper and coax assets at the level desired by the user. Further details on the scenarios and guidelines to operate the Excel model can be found in 'Annex A - User manual for the Excel model'.

3.4. Broadband traffic

One of the critical inputs in the dimensioning of the transmission network is the broadband traffic. The model includes a series of inputs to calculate the broadband traffic that goes through the transmission network in the busy hour (in Mbps) based on the number of subscribers included in the demand section. These inputs include:

⁷ Figures have been normalised to preserve the confidentiality of the operator.



- ▶ **Average download traffic for a representative line of each network:** Which represents the traffic, in GB per year, consumed on average by a typical user in each access network.
- ▶ **Peak to mean ratio:** which represents the ratio between peak and average traffic to calculate the traffic in the busy hour.

These inputs have been populated as described below:

- ▶ In the case of TDC, most of the data is based on data from the operator:
 - Historical figures (2016, 2017 and 2018) are based on the data reported by the operator.
 - Older historical figures (2005-2015) are calculated based on a regression analysis, considering the interannual growth of these figures under each technology.
 - Forecast figures (2019-2038) are determined based on a regression analysis of the interannual growth under each technology, taking into account that growth rates are expected to slow down over time.
- ▶ In the case of Norlys, inputs are also based on data reported by the operator.

3.5. Demand distribution

The demand distribution of the modelled networks determines how the volume of demand of the services included in worksheet '1A INP DEMAND' is allocated to the different geotypes defined in the model. This input is introduced in worksheet '1F INP DEMAND DISTRIBUTION', for the whole modelling period (i.e. from 2005 to 2038) for each geotype separately for the following networks.

- ▶ **Copper access network:** Calculated based on the distribution laid out in DBA's database for broadband demand (active customers).
- ▶ **Fibre PON access network:** Given that the coverage and demand inputs for fibre are dynamic, a different approach has to be followed in this case. The input is calculated assuming that take-up follows an increasing trend over time. This means that, for a given year, regions that have been covered earlier will have a higher take up compared to regions that have been recently deployed. Demand distribution for the PON access network relies heavily on the coverage input extracted from the R model.



- ▶ **Fibre PTP access network:** An equivalent procedure to the one followed for the fibre PON network is performed in this case.
- ▶ **Coax access network:** Equivalently to the input for the copper network, this input is calculated considering that all geotypes have an equivalent take-up. Demand distribution is considered to be constant for every year, similar to the coverage input.
- ▶ **All access networks:** This input is calculated by weighting the distribution of demand of the different access networks by the total traffic (Mbps) in each access network. The total traffic per access network is obtained by multiplying the demand in lines with the average consumption per line.
- ▶ **Multicast:** This input is calculated by calculating the number of Central Offices associated to each geotype and dividing it by the total number of Central Offices in the network.
- ▶ **Fibre networks:** This input is calculated by weighting the distribution of the PTP fibre and PON fibre, based on their demand.

3.6. Network efficiency adjustment

The deployment of access networks is linked to several complex drivers, including historical, technical and strategic factors. One of the key decisions to be made is to decide how many central offices shall be deployed and where they shall be located. Logically, the higher the number of COs (being the number of buildings covered equal), the closer these COs will be to the end user. In turn, this implies that, the higher the number of COs, the lower the costs from the access networks (cables, trenches, ducts) and the higher the costs from the COs. Finding the optimal balance is thus a complex task.

As part of the geographical analyses performed, we have carried out a detailed comparison between TDC's and Norlys' access networks, especially in terms of their average distance between the CO and the users' premise. Particularly, this analysis involved the following steps:

- ▶ **Step 1:** Determining the COs used by TDC and Norlys to cover the area served by Norlys.

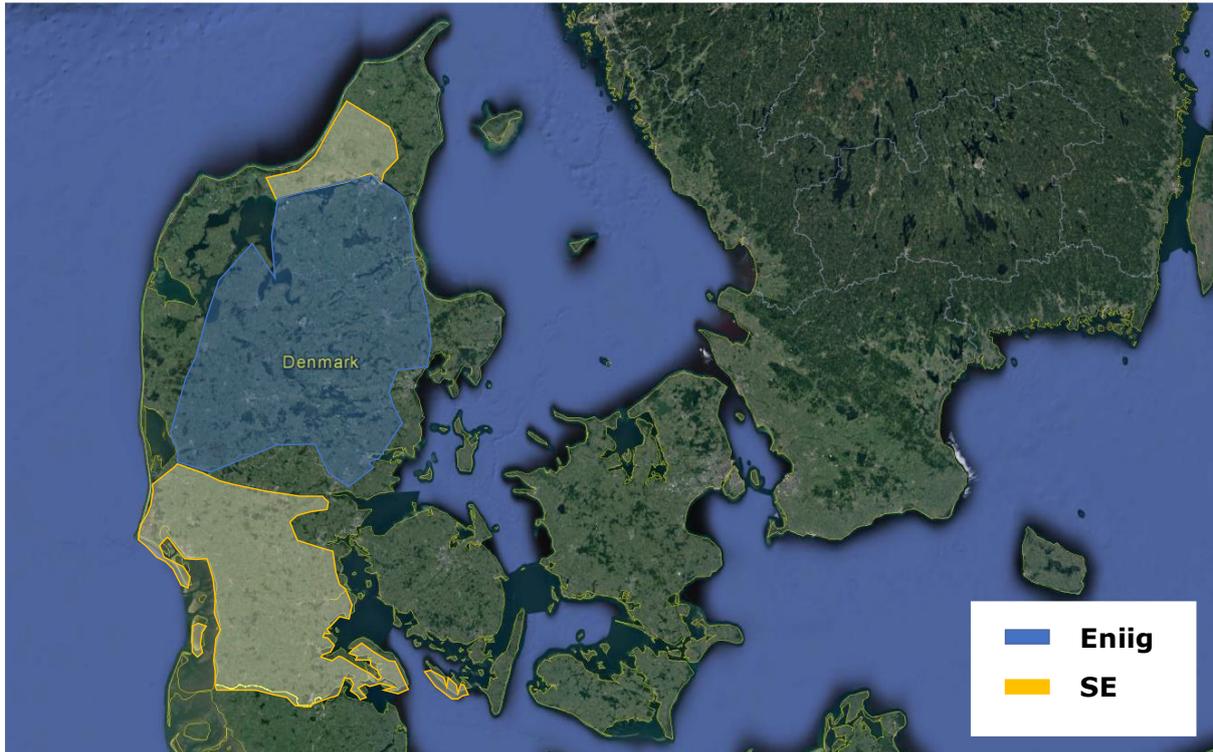


Exhibit 3.7: Coverage areas of Norlys networks [Source: DBA]

Results show that, while TDC has 495 COs in that area (including COs used to provide services under any access technology), Norlys has 392.

- ▶ **Step 2:** Identifying a group of “equivalent” COs between TDC and Norlys. These “equivalent” COs were defined as those that were within a distance of 250 meters between the two operators. A total of 40 COs (40 COs from TDC and 40 COs from Norlys) fulfilled this criterion. Out of these 40, we only selected the 37 that were located in a “Rural” geotype to maximise the representativeness of the exercise.
- ▶ **Step 3.** We analysed the following indicators at CO level for TDC and Norlys:
 - Homes passed (covered).
 - Trenches required to cover the homes passed (please, see the R model manual for further details on the calculation of the Kms. of trenches required).
 - Ratio of trenches required per home passed, calculated by dividing the two items above. This ratio is a good indicator of the costs that would be ultimately borne by each operator, as most of the costs of deploying access networks are distance-related.



This analysis showed that, on average of the 37 COs assessed, Norlys' ratio of trenches per home passed was 15,46% higher than TDC's, as shown below.

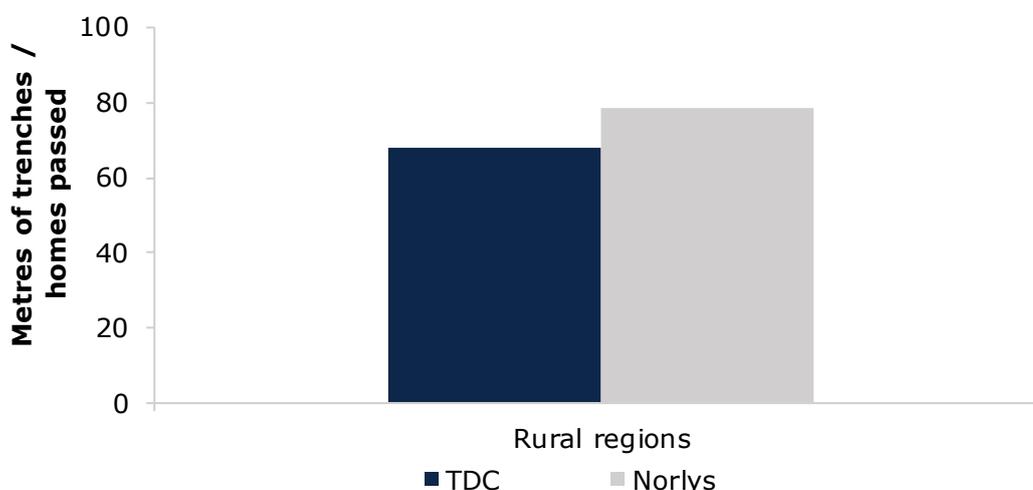


Table 3.1: Ratio of trenches per home passed [Source: Axon]

Given all the considerations that have been adopted to perform this exercise, we conclude that this difference is most likely driven by differences in the access network deployment between the two operators. More importantly, we consider that the difference is derived from the fact that for the COs considered in the analysis, 3,86% of the homes covered by Norlys are more than 10km away from the CO⁸, whereas this percentage is just 0,04% for TDC.

DBA considers that it could be argued that the differences above show a less-efficient access network deployment for Norlys than for TDC. As a result, it has defined an "efficiency adjustment" factor in worksheet '1C INP NW' of the Excel model to account for this difference. The efficiency adjustment has two legs:

- ▶ **Adjustment for distance-related assets:** This includes the aforementioned percentage with the differential between TDC and Norlys for the ratio of trenches per home passed in rural environments. This figure is applied to the results of the KPIs from the R model for assets that are distance-related (e.g. trenches, cables, ducts).

⁸ Considering the road distance resulting from the R model.



This effectively reduces the number of assets estimated by the R model for Norlys, seeking alignment with those that would be needed by TDC.

- ▶ **Adjustment for the number of COs:** Given that one of the main drivers of the potential inefficiencies identified stems from the lower amount of central offices deployed by Norlys. The efficiency adjustment takes this into consideration, determining that, as a trade-off, to reduce the number of trenches per home passed, additional COs would need to be deployed. The percentage included in the model has been calculated to ensure consistency in the number of COs of the operator within the same region.

3.7. Non-network overheads

Corporate and other non-network overheads represent additional costs that the operators incur to support their functions. Examples of these costs include costs associated with corporate headquarters, senior management and internal audits. The Excel model includes non-network overheads in worksheet "1C INP NW" of the cost model. These costs are included in the model as a percentage of total network costs (mark-up). The cost categories that are included in the model are the following:

- ▶ **G&A mark-up:** this mark-up represents the costs of general and administrative activities. This mark-up has been calculated using the following formula:

$$\% \text{ G\&A mark - up} = \frac{\text{Support and overheads costs (relevant for LRAIC model)}}{\text{Total network costs (relevant for LRAIC model)}}$$

Where the total support and overhead costs have been extracted from the Accounting Separation results of the modelled operator for the products relevant for the LRAIC model.

- ▶ **IT mark-up:** additional costs incurred by operators due to IT platforms. This mark-up has been calculated using the following formula:

$$\% \text{ IT Platforms mark - up} = \frac{\text{IT platform costs (relevant for LRAIC model)}}{\text{Total network costs (relevant for LRAIC model)}}$$

Where the IT platform costs have been extracted from data reported by the modelled operator for the IT systems that handles customers, orders, agreements, provisioning and pricing, for example Columbus and Columbine for TDC.



- ▶ **Wholesale and commercial mark-up:** additional costs incurred by operators due to specific wholesale and commercial costs. This mark-up has been calculated based on the cost accounts of the modelled operator using the following formula:

$$\% \text{ Wholesale mark - up} = \frac{\text{Wholesale and commercial costs (relevant for LRAIC model)}}{\text{Total network costs(relevant for LRAIC model)}}$$

Where the wholesale and commercial costs have been extracted from data reported by the modelled operator specifically for this purpose.

- ▶ **Working capital mark-up:** referring to the costs of maintaining daily operations at an organization.

$$\% \text{ Working capital mark - up} = \frac{\text{Working capital}}{\text{Total network costs(relevant for LRAIC model)}}$$

Due to the lack of data, this input is set to zero in the cost model.

Non-network costs are allocated to services based on an equi-proportional mark-up methodology.

3.8. Ancillary services inputs

The inputs to calculate the costs of ancillary (non-recurring) services are introduced in worksheet '1E INP ANCILLARY SERV' of the model. The main inputs required to calculate the costs of these services are:

- ▶ Wages per employee category (technician and administrative) in DKK per minute of work.
- ▶ For each ancillary service, the number of minutes required to perform each one of the following activities:
 - For administrative employees:
 - Processing of order
 - Customer service
 - Annulment fee
 - For technicians
 - Processing of order



- Testing and monitoring/supervision
 - Installation
 - Projecting and planning
 - Customer service
 - Transport
- ▶ For each ancillary service the yearly capital costs associated with the provision of the service, along with an annual cost trend.

For the most part, the information used to populate these inputs is based on the information included in the previous model for 2018, as these have been verified and tested by the industry in relation to the annual pricing decisions issued by DBA.

For description of ancillary services modelled, please see Annex B

3.9. Other network and costing inputs

Finally, the model includes other network and costing inputs that are also relevant to either dimensioning the network or calculate the costs of the services. These are described below, grouped between year-independent and year-dependent inputs.

Year-independent inputs (included in worksheet '1C INP NW'):

- ▶ **Access network inputs:** Includes information concerning the assets available in each access network, such as the number of pairs per copper cable. This information has been extracted from the data reported by the modelled operator.
- ▶ **Transmission and core network inputs:** Includes inputs such as the capacity of the transmission ports, redundancy of routers and number of landing stations. This information has been extracted from the data reported by the modelled operator.
- ▶ **Constants,** as the number of bits per byte or the number of seconds in a year. These constants are industry standards.
- ▶ **Churn,** the percentage of lines that are inactive but have a drop installed. This information has been extracted from the data provided by the modelled operator.



- ▶ **Sharing with utility companies:** this input represents the percentage of the trenches that are shared with utility or other types of companies. This input is defined based on the figures included in the existing LRAIC model.
- ▶ **CCAP:** This input represents the total of CCAP equipment in the network. It is only considered for some coaxial networks and it is considered that the same number of CCAP are considered in the full modelling period.
- ▶ **Other inputs,** as the characteristics of the buildings in Denmark, the average drop length, etc.

Year-dependent inputs (included in worksheet '1D INP NW EVO'):

- ▶ **Coax spectrum dedicated to each service:** Allocation of the spectrum to the different services provided over the coax network (broadband, TV, VoD). This information has been extracted from the data provided by the modelled operator.
- ▶ **Traffic per Leased Line:** Average traffic in the busy-hour reserved for uncontended traffic (in Mbps) for each type of leased line (Legacy and IP Fibre). This information has been extracted from the data provided by the modelled operator.
- ▶ **Inflation:** Evolution of prices in the country, used to estimate the OpEx trends. Extracted from OECD and European Commission databases.
- ▶ **Productivity:** Evolution of the efficiency of staff operations. This has been extracted from OECD databases.
- ▶ **Percentage of homes passed that are connected:** Presents the evolution in terms of the percentage of homes passed that are connected for each fibre network (PON and PTP).
- ▶ **Up-front Payments:** Total yearly amount received by the operators from customers to perform installations of the fibre NTP in their houses
- ▶ **Subsidies:** Total yearly state aid amount received by the operators to deploy fibre access networks.

When applicable, these figures have been cross-checked against different references, such as:

- ▶ Axon's internal databases.
- ▶ Information from the previous DBA's model for the year 2018.



4. Geographical inputs

The design of fixed access networks requires an extensive analysis of the geographical zones to be covered, as it will have a direct impact on the dimensioning of networks resources that are dependent on the underlying geography, like cables, trenches, etc. This analysis is performed in the R model (see the R model manual for detailed explanations on the calculations and algorithms included in the R model). The results of the R model are loaded into the Excel model in the control panel (see 'Annex A - User manual for the Excel model' for further details on the process of loading the results of the R model into the Excel model). Several key inputs are loaded from the R model into the Excel model:

- ▶ Network coverage
- ▶ Access network elements and distribution
- ▶ Core network inputs
- ▶ Other geographical inputs

Each of these sets of inputs is explained in the subsections below.

4.1. Coverage

Coverage inputs included in worksheet '2A INP COVERAGE' refer to the percentage of homes passed by each access network per geotype and year. These inputs are defined for the following networks:

- ▶ Copper networks
- ▶ Fibre PON networks
- ▶ Fibre PTP networks
- ▶ Coax networks

The coverage percentages outlined in this worksheet can be multiplied by the number of buildings and the number of homes per building included in worksheet '2E INP NW OTHER' to calculate the total number of homes covered by each technology.

These inputs are presented at geotype level and are loaded from the R model. Please, see the R model manual for further details on the calculation of these inputs.



4.2. Access network elements and distribution

The design of fixed access networks requires an exhaustive analysis of the geographical areas to be covered, as they will have a direct impact on the dimensioning of the network assets that are dependent on the underlying geography, such as cables, trenches, etc.

These calculations are performed in the R model and described in the R Model Manual. The outcomes of the R model are then loaded into the worksheets '2B INP NW INVENTORY' and '2C INP NW ELEMENT DIS' of the Excel Model.

The access network inputs produced in the R model are:

- ▶ Copper access network:
 - Km of copper trenches
 - Km of cables (pairs)
 - Km of fibre cable for copper network
 - Number of street cabinets
 - Number of DPs
 - Number of MDFs
 - Number of COs
 - Number of joints
 - Others, such as the percentage of homes connected directly to a Central Office and the distribution of the configurations of the different equipment. All parameters produced by the R model for the copper access network are available in the worksheets '2B INP NW INVENTORY' and '2C INP NW ELEMENT DIS' of the Excel model.

- ▶ Fibre access network
 - Km of fibre trenches
 - Km of strands (PON and PTP)
 - Number of PON OLT
 - Number of joints (PON and PTP)
 - Number of DP



- Number of PTP MSAN
 - Number of ODF
 - Trenches shared with coax networks
 - Others, such as the number of PON Splitters and the configurations of the different equipment. All parameters produced by the R model for the fibre access network are available in the worksheets '2B INP NW INVENTORY' and '2C INP NW ELEMENT DIS' of the Excel model.
- ▶ Coax access network
- Km of coax trenches
 - Km of coax cables
 - Km of fibre cable for coax network
 - Number of CMCs
 - Number of coax OLTs
 - Number of taps
 - Number of coax splitters
 - Number of DPs
 - Others, such as the number of amplifiers and the configurations of the different equipment. All parameters produced by the R model for the coax access network are available in the worksheets '2B INP NW INVENTORY' and '2C INP NW ELEMENT DIS' of the Excel model.

4.3. Core network inputs

As for access networks, transmission networks require an exhaustive geographical analysis, as they have a direct impact on the dimensioning of the network assets that are dependent on the underlying geography, such as cables, trenches, etc.

These calculations are also performed in the R model and described in the R Model Manual. The outcomes of the R model are then loaded into the worksheet '2D INP CORE & TX RINGS' for each transmission network, namely:

- ▶ L3 Access network
- ▶ Aggregation network



- ▶ Distribution network
- ▶ Core network

The transmission network inputs produced in the R model are:

- ▶ Number of nodes
- ▶ Number of rings/chains
- ▶ Total route length of chains
- ▶ The total percentage of traffic handled by each chain

4.4. Other geographical inputs

Other geographical inputs are needed for the dimensioning of the networks. These inputs have been also extracted from the geographical analysis performed in R, they are mainly related to:

- ▶ Average dwellings per building
- ▶ Number of buildings per geotype
- ▶ Share of allocation of core costs
- ▶ Share of the core transmission network shared with the access network
- ▶ Percentage of the network not shared with the access networks
- ▶ Share of the submarine transmission network shared with the access network
- ▶ Percentage of Copper COs with other technologies (fibre or coax)
- ▶ Single dwelling share from SDUs
- ▶ Effective splitting ratio for PON networks

The detail about the algorithms used for their calculation can be found in the R Model Manual.

Additionally, the average drop length is extracted from the previous LRAIC model. This is not calculated through the R model due to limited data on the shape of the buildings.



5. Dimensioning module

The dimensioning module aims at designing the network and dimensioning the network resources required to serve the demand of the modelled operator. This dimensioning is performed in the Excel model and focuses on the calculation of the network elements that depend on the demand (number of active lines), traffic (Mbps) and Spectrum.

Therefore, the main inputs to this module are:

- ▶ Network inputs, such as the network parameters presented in section '3 - Market and network inputs'.
- ▶ Drivers, representing the overall traffic, demand and spectrum.
- ▶ Geographical inputs, the results obtained from the geographical analysis performed in R (please see R Model Manual for more details).

This section presents all the calculations followed for the purpose of the dimensioning of all the network elements. For that, this section has been divided into three different network sections which are described in detail below:

- ▶ **Dimensioning Drivers**, presenting the process for the definition of the drivers
- ▶ **Core and Transmission Network Dimensioning**, introducing the algorithms used for the calculation of Core and Transmission network elements
- ▶ **Access Network Dimensioning**, introducing the algorithms used for the calculation of access network elements

5.1. Dimensioning drivers

The rationale of the dimensioning drivers is to express traffic and demand (at service level) in a way that facilitates the dimensioning of network resources that are dependent on demand volumes (e.g. active equipment).

This section presents the following aspects of dimensioning drivers:

- ▶ Dimensioning drivers' concept
- ▶ Mapping services to drivers
- ▶ Conversion from services to drivers



5.1.1 Dimensioning drivers' concept

The explicit recognition of a dimensioning "Driver" in the model aims at simplifying and increasing the transparency of the network dimensioning process.

Dimensioning drivers represent, among others, the following requirements:

- ▶ Number of connections (copper, fibre and coax) for the dimensioning of the access network.
- ▶ Mbps for transmission through the different layers of the transmission network.

The following list contains the drivers used in the LRAIC costing model for fixed networks:

VARIABLE
DRIV.Access copper.Connections.Total Active connection
DRIV.Access coaxial.Connections.Total Active connection
DRIV.Access fibre.Connections.Total Active connection
DRIV.Broadband.Traffic.Copper broadband - Access
DRIV.Broadband.Traffic.Fibre broadband - Access
...
DRIV.Video.Traffic.Wholesale VoD - Distribution/Core

Exhibit 5.1: Sample list of drivers used in the model (Sheet 'OD PAR DRIVERS'). [Source: Axon]

Two steps are required to calculate the drivers:

1. Mapping services to drivers
2. Converting traffic units into the corresponding driver units

Each of these two steps is discussed below in more detail.

5.1.2 Mapping services to drivers

To obtain drivers it is necessary to indicate which services are related to them. It should be noted that each service is generally assigned to more than one driver as drivers represent traffic in a particular point of the network.

For example, broadband copper services should be contained in both the drivers used to dimension the access network (in order to properly dimension the number of MSANs required) as well as the core networks.



The following exhibit shows an excerpt of the mapping of services into drivers:

DRIVER (Variable Name)	SERVICE (Variable Name)
DRIV.ACCESS COPPER.Connections.Total Active connection	Access.Copper.Retail.Access
DRIV.ACCESS COPPER.Connections.Total Active connection	Access.Copper.Retail.Access with bonding
DRIV.ACCESS COPPER.Connections.Total Active connection	Access.Copper.Wholesale.VULA (POI0)
DRIV.ACCESS COPPER.Connections.Total Active connection	Access.Copper.Wholesale.VULA (POI1)
DRIV.BROADBAND.Traffic.Fibre broadband - Aggregation	Broadband.Fibre.Retail.broadband
DRIV.BROADBAND.Traffic.Fibre broadband - Aggregation	Broadband.Fibre.Wholesale.BSA broadband - POI2
DRIV.BROADBAND.Traffic.Fibre broadband - Aggregation	Broadband.Fibre.Wholesale.BSA broadband - POI3
...	...

Exhibit 5.2: Excerpt from the mapping of Services into Drivers (Sheet '3A MAP DRIVERS') [Source: Axon]

5.1.3 Conversion from services to drivers

Once services have been mapped to drivers, volumes need to be converted to obtain drivers in proper units.

For that purpose, a conversion has been worked out representing the number of driver units generated by each demand service unit. In general, conversion calculation consists of two subfactors, in compliance with the following structure:

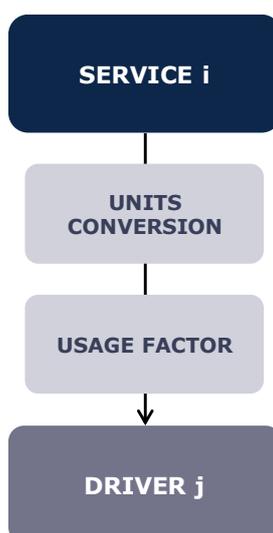


Exhibit 5.3: Conversion Process from Services to Drivers [Source: Axon]



The conversion factor thus includes the following items:

1. Usage Factor (UF)
2. Conversion Factor (CF)

Finally, the relationship between a given service and a driver is obtained by following the formula outlined below:

$$FC = UF * CF$$

Usage factor represents the number of times a service makes use of a specific resource.

Conversion Factor represents the need to adapt services' units (e.g. lines) to those used by the driver (e.g. Mbps). The application of the conversion factors from services to drivers is performed using "weights" (Average traffic per line). These weights are calculated in the worksheet '3A MAP WEIGHTS'.

5.2. Transmission network dimensioning

The objective of the dimensioning of the transmission network is the calculation of the number of network elements required to meet the demand and coverage levels present from the networks of the modelled operator. These network elements include active elements (Routers, ports, etc.) and passive elements (trenches, landing stations, fibre cable, etc.).

As a first instance, the dimensioning of the transmission network is performed at a national level, meaning that geotypes are not considered in the calculation of the results. The dimensioning approach is performed separately for each of the layers in the transmission network:

- ▶ L3 Access Network
- ▶ Aggregation Network
- ▶ Distribution Network
- ▶ Core Network

A summary of the topology considered is presented in the exhibit below:

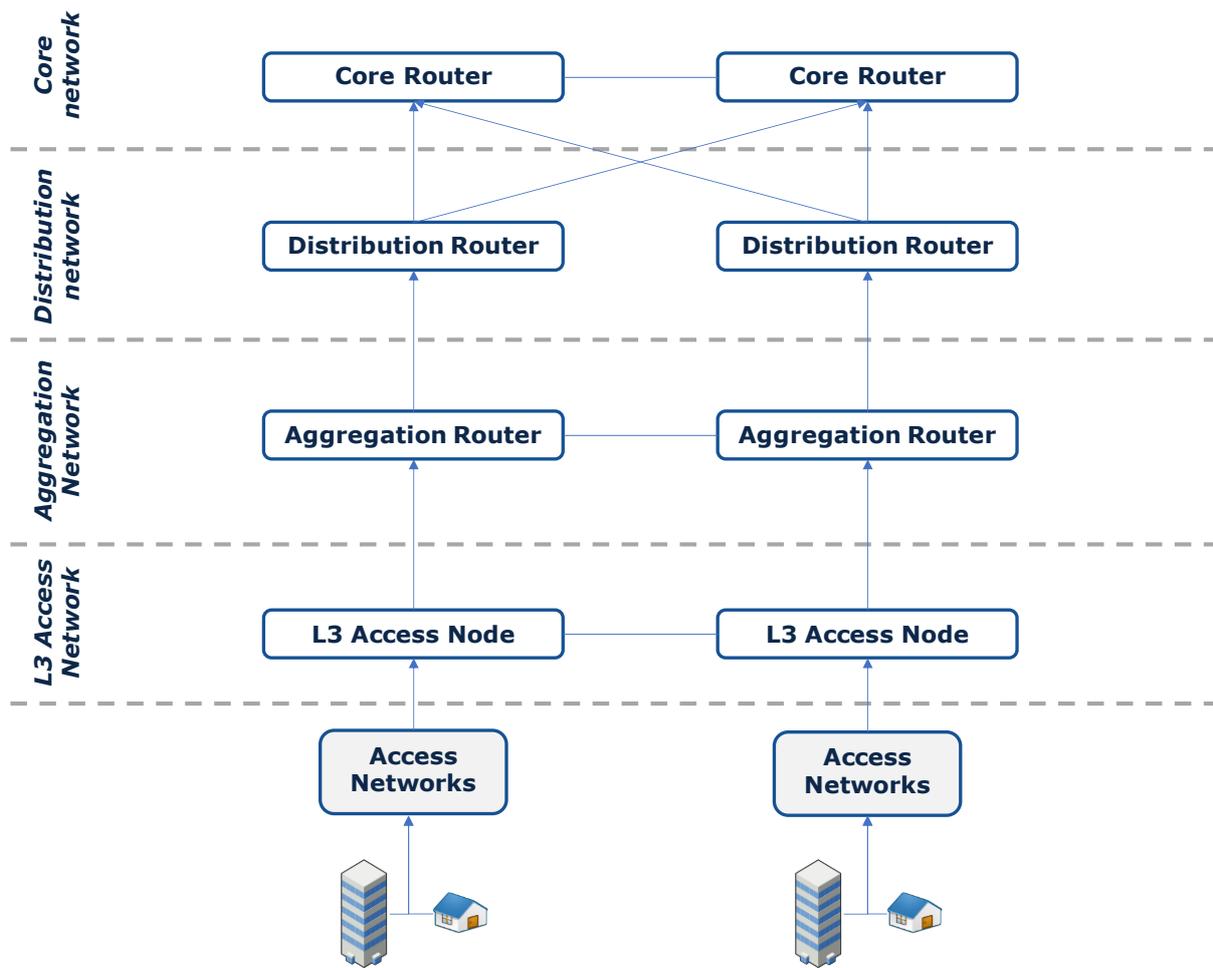


Exhibit 5.4: Architecture of the transmission networks [Source: DBA]

However, it should be noted that the algorithms considered for each layer are equivalent. Thus, below we present the algorithms followed once, capturing any small differences identified.

Router equipment

The number of routers installed in each network layer is determined based on the number of nodes and their associated traffic.

As a starting point, the model considers a single router in each network node. This figure can be increased if the traffic that the router needs to hold is greater than its capacity. In



In addition, the model considers router redundancy for core and distribution router nodes. Hence, in these cases, two routers are installed in each node.

Once the number of routers has been determined, we proceed to the calculation of each one of its elements. The details of the dimensioning of each element are outlined below:

SFP for each network layer (100G, 10G, 1G⁹)

The SFPs correspond to the ports of the routers in the transmission network. Their number and capacity are calculated depending on the traffic managed by each node in the network.

The calculation of the number of SFP per capacity is performed taking into account an algorithm that chooses the most cost-efficient solution. The process consists of the following steps:

- ▶ The maximum number of SFP of 100G are calculated.
- ▶ The rest of traffic not covered by the SFPs (100G) is used to calculate the number of SFPs of 10G required. In this step, the model checks the most cost-efficient solution. Indeed, if the number of 10G SFPs is higher than the ratio between the cost of the 100G over 10G, the model chooses to install a 100G SFP.

⁹ The 1G SFPs are not used in the core and distribution networks, as at this aggregation level the traffic handled by the equipment is higher.

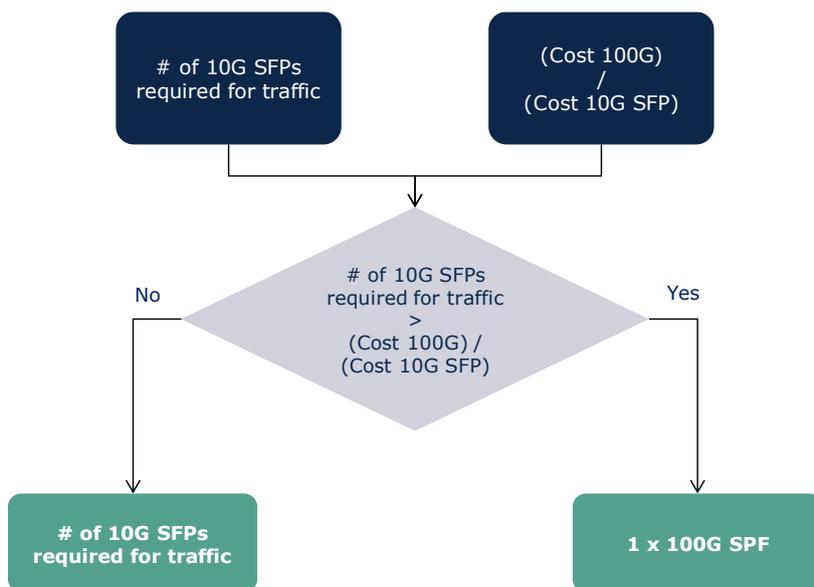


Exhibit 5.5: Algorithm to choose the most cost-efficient solution for SFPs [Source: Axon]

The same steps presented above are followed considering 10G SFPs and 1G SFPs.

In addition, the model considers the redundancy in the ports of the core routers to ensure the resiliency of the network. Finally, the model adjusts the number of ports to ensure that a maximum load factor is respected to ensure the resiliency of the network.

The output of this process is the number of SFPs required for capacity in the core and transmission network.

SFP for interconnection between network layers

In addition to the ports associated to the actual routers required for each layer, the model includes additional ports to interconnect the different network layers (e.g. the distribution layer to the lower aggregation layer).

The number of SFPs required for interconnection between each transmission layer and the next lower layer of the network are calculated as follows:

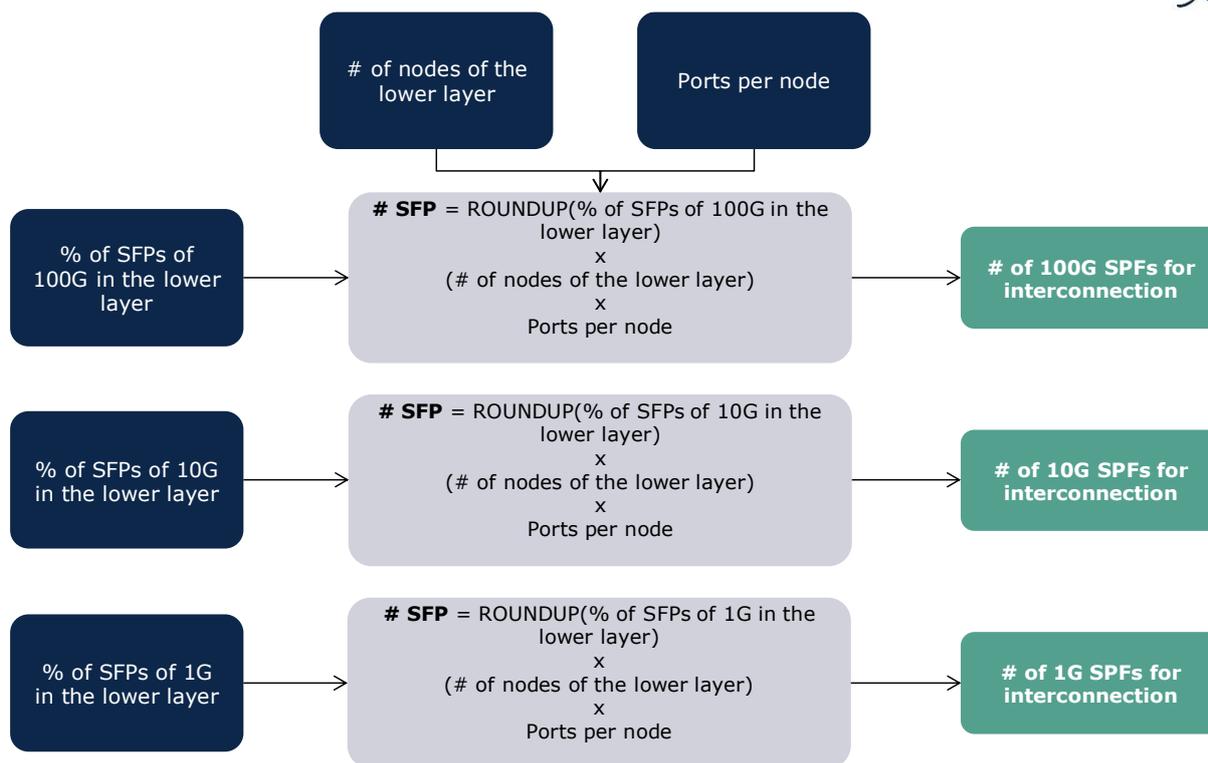


Exhibit 5.6: Algorithm for the calculation of the number of SFPs for interconnection required
[Source: Axon]

The output of this process is the number of SFPs required for interconnection in the core and transmission network.

Number of subracks

The number of subracks, which are cards of ports (SFPs) installed in the transmission routers, depends on the number of ports that the subrack installed in each transmission layer can manage. Subracks are disaggregated depending on the capacity of the ports installed in them (1G, 10G or 100G). The calculation of the number of subracks is performed separately for each layer for each of the different capacity configurations defined. The process is as follows:

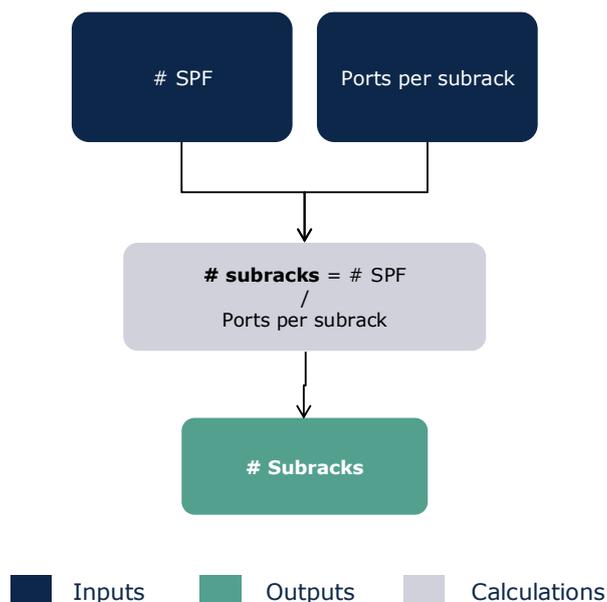


Exhibit 5.7: Calculation of number of subracks [Source: Axon]

In addition, the model includes a minimum of two subracks are installed in each distribution and core router to account for network redundancy.

Number of racks

The number of racks, which aggregate the subracks installed in the transmission routers, depends on the number of subracks that the rack installed in each transmission layer can manage. Similarly, to the SFPs and the subracks, the racks are disaggregated depending on the networks speed they have to handle. The calculation of the number of racks is disaggregated depending on the network layer and for each of the capacity configurations of the racks (1G, 10G and 100G). The calculation is performed as follows:

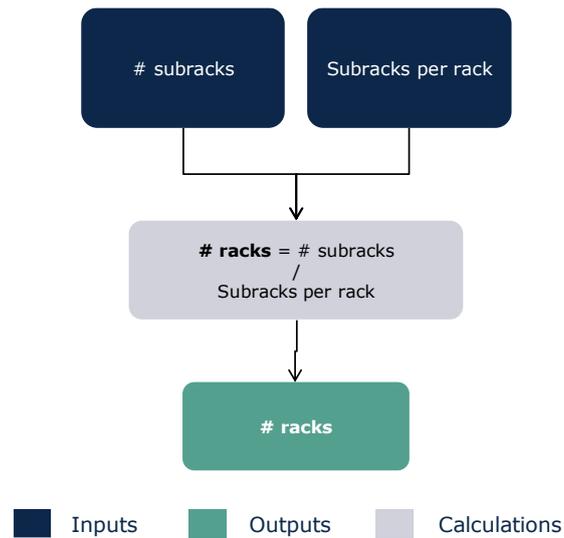


Exhibit 5.8: Calculation of number of racks [Source: Axon]

In addition, the model includes a minimum of two racks for each distribution and core router to account for network redundancy.

Number of chassis

The number of chassis, which are the main body of the transmission routers themselves, depends on the number of racks that each router in each transmission layer can manage. The calculation of this figure is performed as follows:

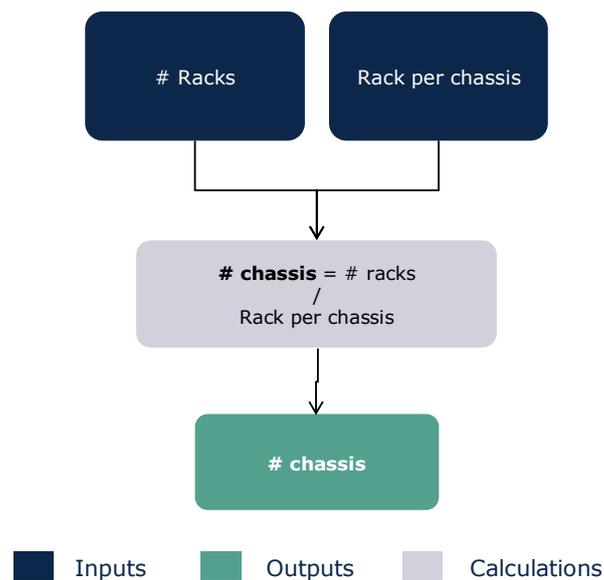


Exhibit 5.9: Calculation of number of chassis [Source: Axon]



Sites

The number of sites, which represent the physical location where the routers are installed, determined in the model is simply calculated as the total number of node locations of each network.

DWDM Equipment

The DWDM network is modelled under the assumption that only the core and distribution networks would need to deploy these network elements. L3 Access and aggregation networks do not include DWDM equipment, as it is estimated that the traffic these networks handle is not sufficient to consider these additional investments.

To estimate the number of DWDM network elements, the model inspects, for each network node in the core and distribution layer, the following aspects:

- ▶ Directions for the DWDM network: this input refers to the number of network nodes to which each DWDM needs to be connect to. The model installs in each node one platform (that can be used for a single direction) plus the additional number of directions needed based on the network's topology.
- ▶ Line cards and ports for the DWDM network: The model estimates the number of line cards necessary for each network node, considering the traffic handled in the network node and assuming that each line card and port can handle 100 Gbps.
- ▶ Amplifiers: the model considers that the DWDM platforms in the core network may require an additional amplifier. No amplifiers are considered for those in the distribution network.

Submarine cables and Landing stations

The list of submarine cables and their distance used in this network are known (please see R Model Manual for further details on this aspect). Therefore, the total distance of submarine cables is equivalent to the sum of the distance of each of the submarine cables dedicated to each one of the transmission networks.

On the other side, the number of Landing stations is calculated supposing that each submarine cable needs 2 landing stations.



Fibre cable

The total length of fibre cable used in each layer of the transmission network is calculated as the following:

$$k \cdot \sum_1^N \text{Distance route of ring/chain}(i)$$

- ▶ Where i represents each of the ring/chains of the layer of the transmission network.
- ▶ Where k is equal to 2 when deployment of additional fibre for redundant links between the routers of the network is needed to ensure the resiliency of the network. This will be the case mainly for the core and distribution networks.

Trenches

Trenches represent the civil infrastructure required to deploy the fibre transmission cables.

As presented in the R Model Manual, the model takes into consideration that some of the routes followed by the layers of the transmission network are shared with the civil infrastructure of the access networks.

Based on this, the following algorithm has been used to calculate the trenches of the transmission network:

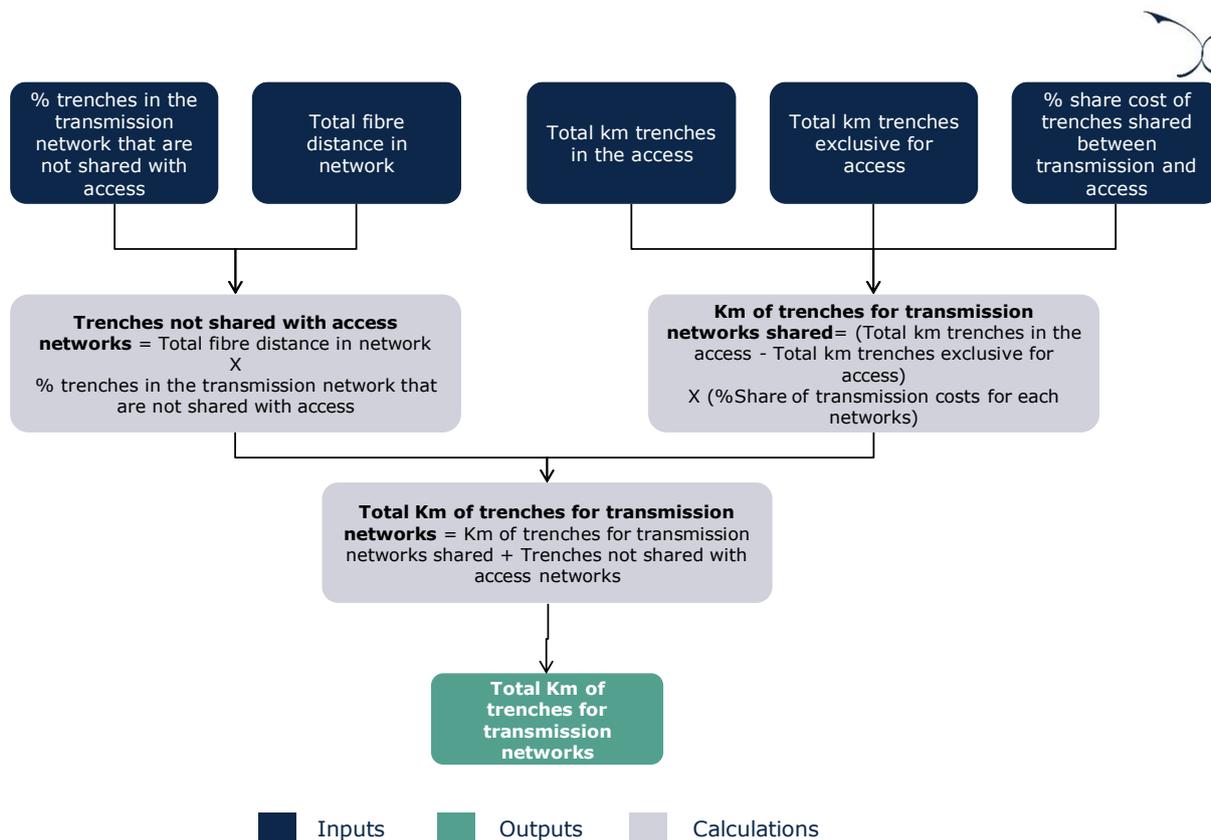


Exhibit 5.10: Algorithm for the transmission trenches calculation [Source: Axon]

Allocation of transmission elements into geotypes

The dimensioning of the core and transmission networks is performed independently of the geotype. Nevertheless, to obtain disaggregated costs, the results of the dimensioning must be distributed to the geotypes. In order to do so, two drivers¹⁰ have been calculated for each network (L3 Access, Aggregation, Distribution and Core):

- ▶ **Traffic share per geotype:** allowing the allocation of the resources depending on the traffic as routers, cards, ports, etc.
- ▶ **Distance share per geotype,** to distribute the resources depending on distance as cables and trenches.

¹⁰ These drivers have been extracted from the geographical analysis.



Therefore, the results are multiplied by those drivers in order to distribute the transmission resources in geotypes.

5.3. Access Network Dimensioning

The dimensioning of the access network is performed separately for each of the geotypes defined, to accurately reflect the impact of the geographical characteristics of Denmark in the deployment of access network elements. The dimensioning approach employed has been divided into three different blocks, namely:

- ▶ Copper Access Network Dimensioning
- ▶ Fibre Access Network Dimensioning
- ▶ Coax Access Network Dimensioning

5.3.1 Copper Access Network Dimensioning

The dimensioning algorithm for copper access networks is organized into five steps, as shown in the chart below:

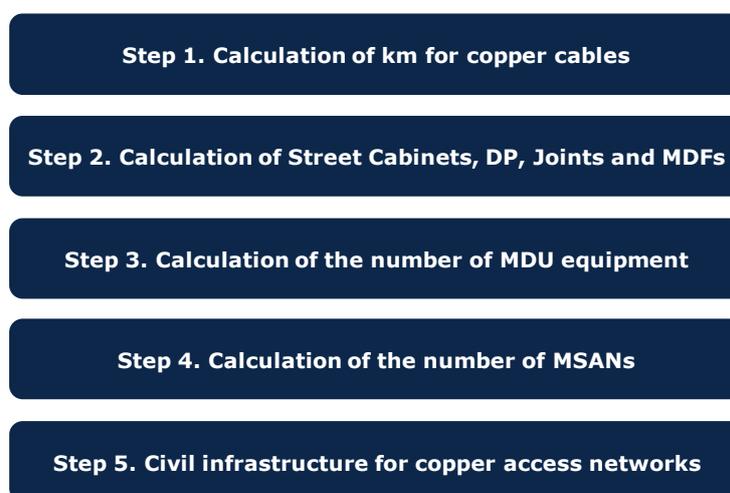


Exhibit 5.11: Steps followed for the dimensioning of copper network elements [Source: Axon]

The dimensioning algorithm for the copper access network is implemented in worksheet '5B DIM GEO' of the model for each one of the geotypes. The following subsections provide further detail about each specific step of the algorithm.



Step 1. Calculation of km for copper cables

The first step in the dimensioning of the copper access network consists of the calculation of the number of cables required. The copper access network is composed of three main types of cables:

- ▶ Final Drop Copper Cables
- ▶ Copper cables used between the FDP and MDF
- ▶ Fibre cables used between the MDF and CO

The number of such elements is calculated according to the algorithms outlined below:

Final drop copper cables

The final drop cables are used in the copper network to connect the households to their assigned FDP. The copper drop cables consist of:

- ▶ A horizontal cable, defined as the direct distance from the house until the side of the street multiplied by a non-optimal factor.
- ▶ A vertical cable, representing the internal cabling needed to reach each floor for MDU buildings. This also includes the cable from the trench until the ground floor.

Therefore, the total length of drop cables is calculated following the algorithm below:

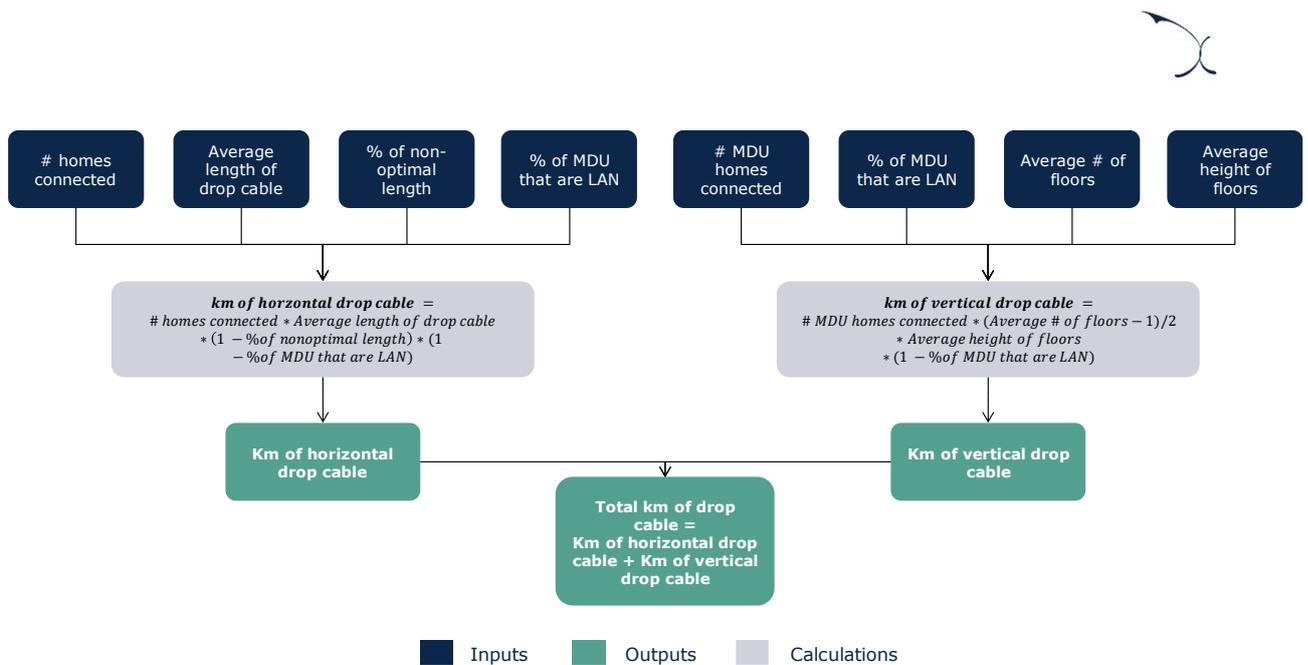


Exhibit 5.12: Algorithm for the calculation of the copper drop cables [Source: Axon]

Please note that the number of homes connected has been calculated based on the data reported by the operator. All cables are then adjusted by a factor for excess cables to mimic the waste generated during installations.

Copper cables used between the FDP and MDF

The total distance of copper cables used to connect from nodes FDP to MDF nodes and the percentage of each type of cable deployed have been calculated in the R Model. Therefore, considering this information as input, the kilometres per type of cable have been determined as follows:

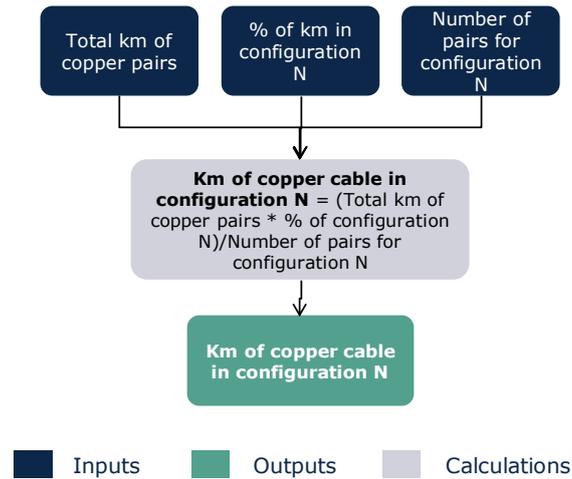


Exhibit 5.13: Algorithm for the calculation of the length of copper cables per configuration [Source: Axon]

The N configurations introduced in the model for copper cables are 4, 10, 20, 50, 100, 200, 400, 600, 800 pairs. All cables are then adjusted by a factor for excess cable to represent the waste generated during installation.

Fibre cables used between the MDF and CO

The total distance of fibre cable used to connect the MDFs to the COs in the Copper Access network have been determined in the geographical analysis. This cable has only one possible configuration (12 strands), and therefore the result from the geographical analysis is directly entered for this resource. All cables are then adjusted by a factor for excess cable to represent the waste generated during installation.

Step 2. Calculation of Street Cabinets, DPs, Joints and MDFs

The second step focuses on the calculation of the Street Cabinets, DPs, Joints and MDFs. The total number of these elements and the percentage of each of their configuration are known (extracted from the outputs of the R Model) and introduced in the Excel model.

The calculation flow is similar for all the elements modeled in this step. The following exhibits present the algorithm implemented for the DPs:

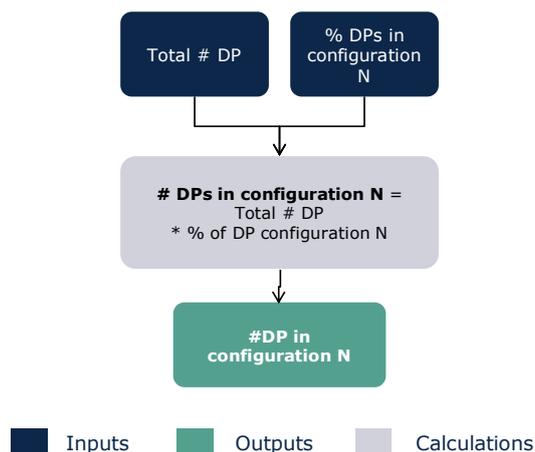


Exhibit 5.14: Algorithm to determine the number of copper DPs [Source: Axon]

The modelling of the MDFs, joints and Street Cabinets is equivalent to that of Distribution Points but considering their configurations. The available configurations for each element are presented in the table below:

DP configurations	SC configurations	Joints configurations	MDF configurations
Copper DP - 5 pairs	Copper SC - 192 subs.	Copper joint - 10 pairs	MDF - 250 subs.
Copper DP - 10 pairs	Copper SC - 384 subs.	Copper joint - 50 pairs	MDF - 500 subs.
Copper DP - 20 pairs		Copper joint - 100 pairs	MDF - 2000 subs.
Copper DP - 50 pairs		Copper joint - 300 pairs	MDF - 12000 subs.
Copper DP - 100 pairs			MDF - 48000 subs.
Copper DP - 500 pairs			
Copper DP - 1000 pairs			
Copper DP - 2000 pairs			

Exhibit 5.15: Configurations of Street Cabinets, DPs, Joints and MDFs [Source: Axon]

Step 3. Calculation of the number of MDU equipment

The third step presents the calculation of requirements for equipment specific for MDU buildings. This calculation involves the estimation of the number of connected buildings that are MDUs. The algorithm followed to calculate the number of MDU equipment is outlined below:

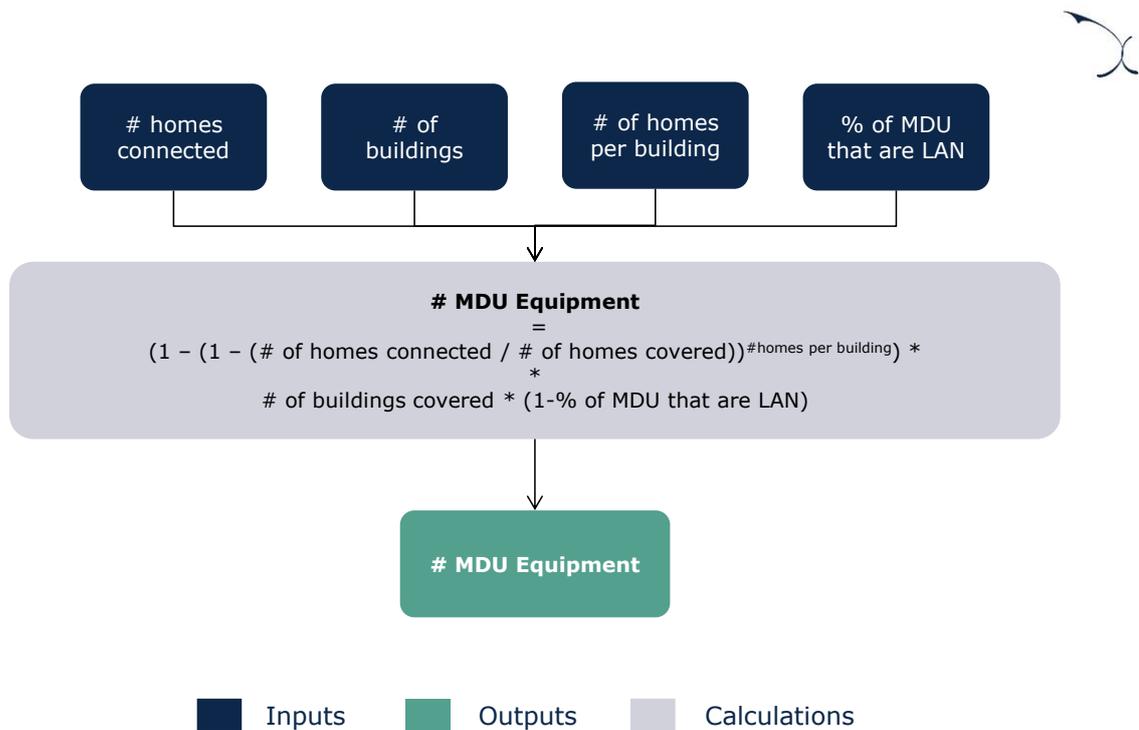


Exhibit 5.16: Calculation of the number of MDU equipment [Source: Axon]

Step 4. Calculation of the number of MSANs

Once the previous elements are determined we proceed to calculate the number of MSANs required for the network. The model considers two main types of MSAN depending on their location:

- ▶ Local MSAN: located in the CO
- ▶ Remote MSAN: located in the street cabinets

Additionally, the number of ports required in the L3 access nodes used to connect to the access nodes (MSANs) are calculated.

Local MSANs

The local MSANs are placed in the CO to serve the homes that are directly connected to the COs. The algorithm followed to calculate the number of local MSANs is outlined below:

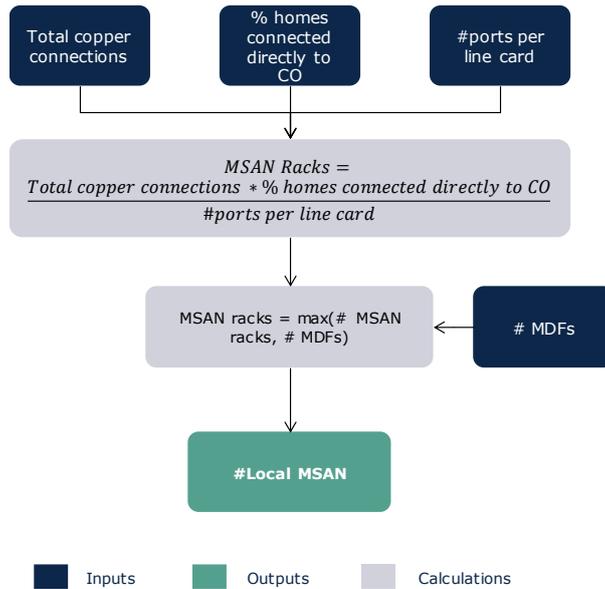


Exhibit 5.17: Algorithm for copper Local MSANs [Source: Axon]

Remote MSANs

The Remote MSANs are considered as the MSANs that are located in the Street Cabinets and are placed to serve all the homes that are not directly connected to COs. Therefore, the calculation performed to determine their number is the same as for local MSAN considering the number of homes not connected directly to the COs.

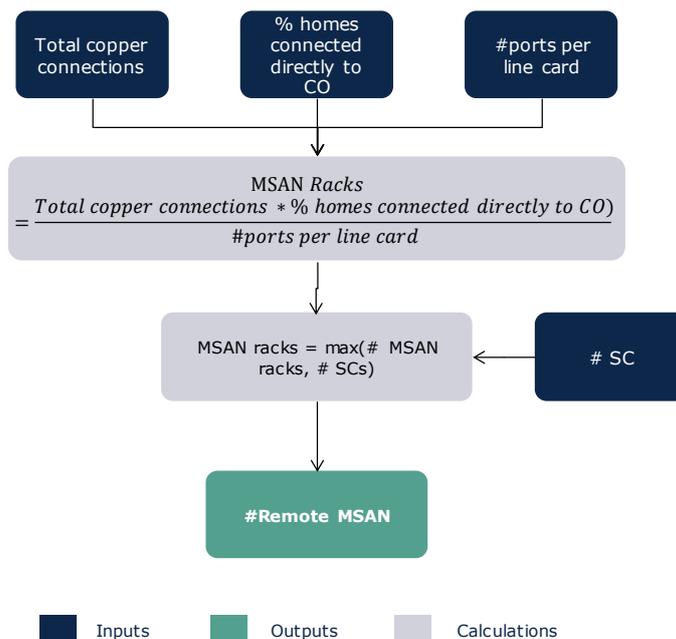


Exhibit 5.18: Algorithm for copper Local MSANs [Source: Axon]

Ports for access nodes

These ports are located in the L3 access nodes and are used to connect the copper MSANs with the core and transmission networks. Therefore, the calculation performed to determine their number follows the steps below:

1. Calculation of the broadband traffic per node

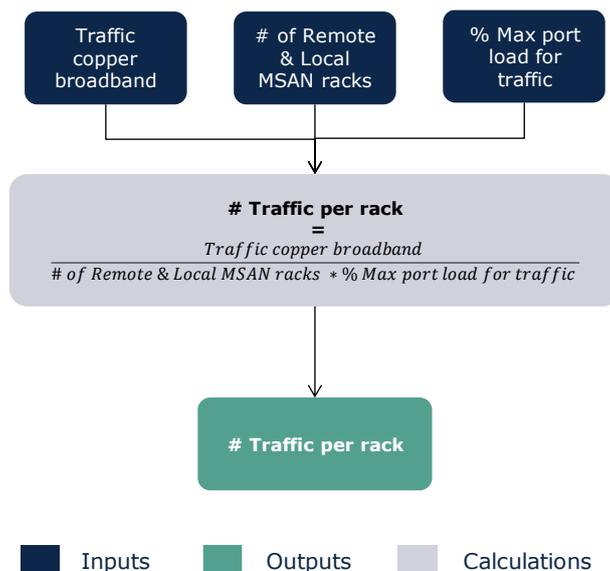


Exhibit 5.19: Calculation of the number of ports required to connect the access nodes [Source: Axon]

2. Calculation of the number of SFPs ports needed to handle the traffic. The selection of the SFPs is performed selecting the most cost-efficient solution. The algorithm followed for this is presented in the section 5.2. Transmission network dimensioning’.

Step 5. Civil infrastructure for copper access networks

The last step is related to the dimensioning of the civil infrastructure required for the copper access network. The civil infrastructure required for this technology consists of:

- ▶ Home-FDP trenches: these are the trenches dug for final drop cables
- ▶ Road crossing trenches: trenches dug when there is a need to cross a road.
- ▶ FDP-MDF trenches: required for the buried copper cables used in this part of the network
- ▶ MDF-CO trenches: required for the buried fibre cables used in this part of the network
- ▶ Ducts
- ▶ Joint holes and Manholes

In the following sections, the calculations done in order to determine these elements are presented.



Home-FDP Trenches

The total km of trenches for the final drop cables are calculated using the following algorithm:

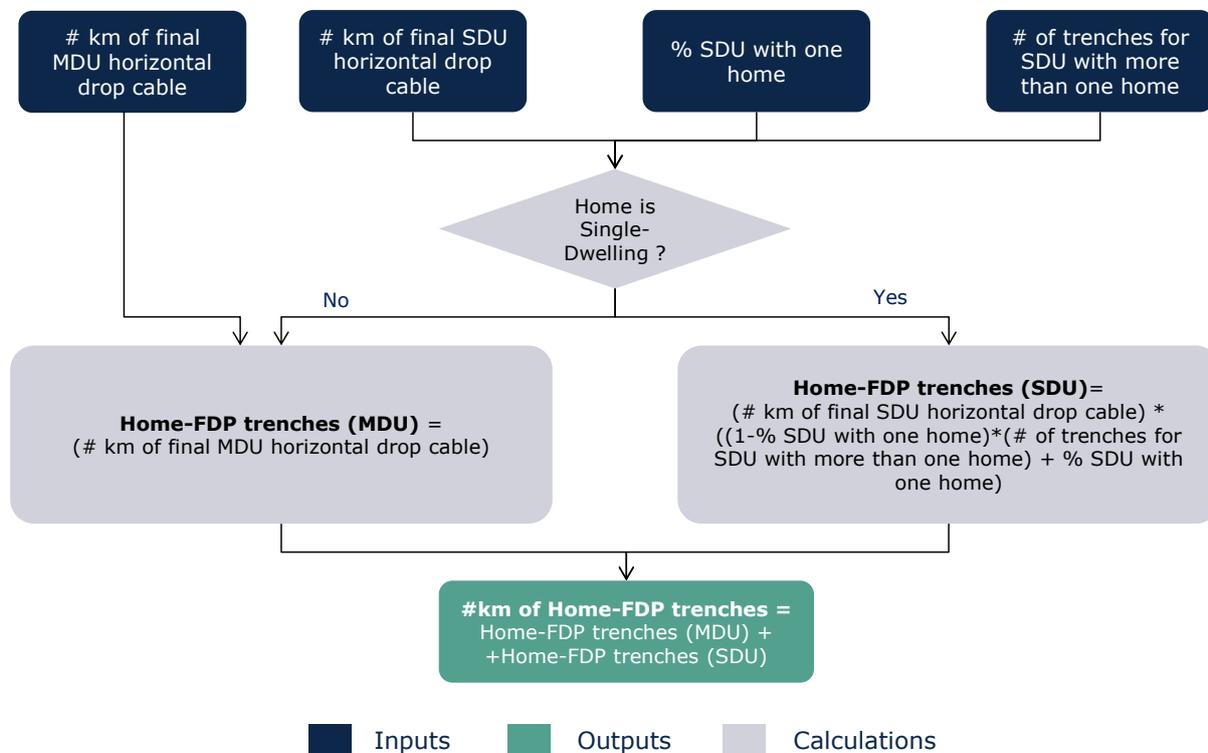


Exhibit 5.20: Calculation of Home-FDP trenches [Source: Axon]

Road crossing trenches

In addition, the model includes the trenches related to the road crossings that are extracted from the geographical analysis.

FDP-MDF trenches

The geographical analysis allowed the calculation of the total length of trenches required for the copper access network. However, this total distance contemplates the hypothetical case where there was no sharing of these trenches. In actuality, the trenches could be shared with other access technologies, the core network or even utility companies.



In this section we present the adjustments done in order to settle the number of km that are used exclusively for access networks, distinguishing the part that is shared with transmission and core networks.

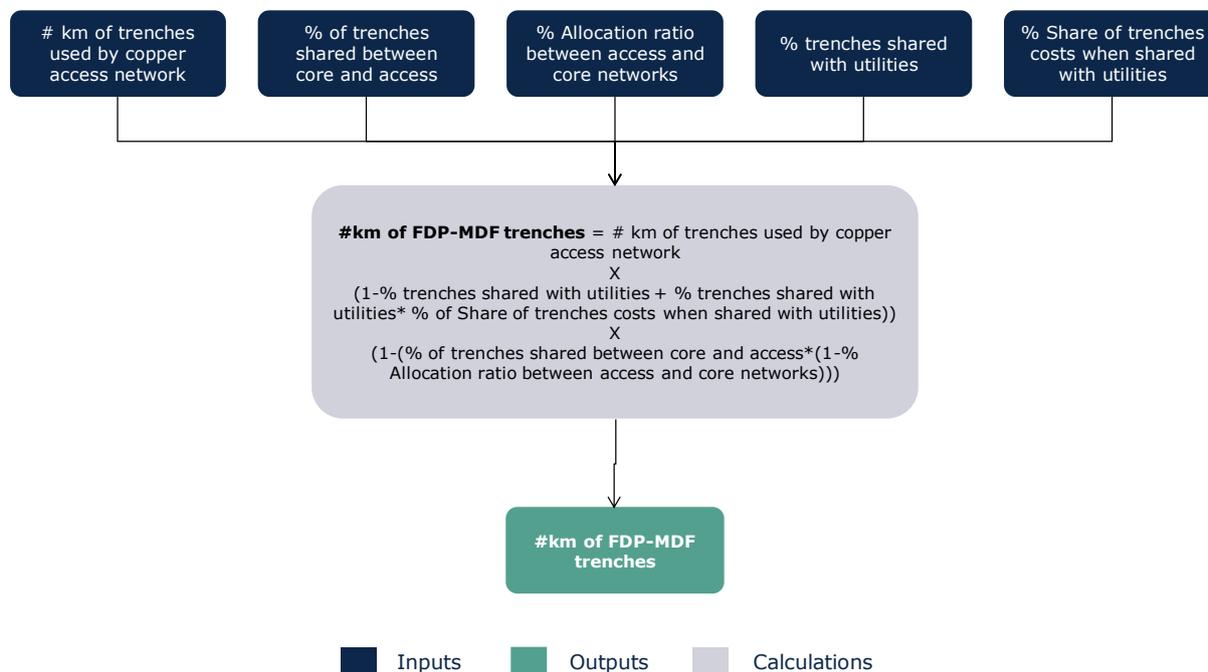


Exhibit 5.21: Calculation of FDP-MDF trenches [Source: Axon]

MDF-CO trenches

The geographical analysis allowed the calculation of the total length of trenches required for the MDF-CO connections for the copper access network. As for the FDP-MDF trenches, this part of the network can also be shared. In order to consider this sharing, the same algorithm as for FDP-MDF trenches has been followed.

Ducts

Part of the cables of the copper network is introduced in ducts. Hence, the calculation of km of ducts follows the algorithm below:

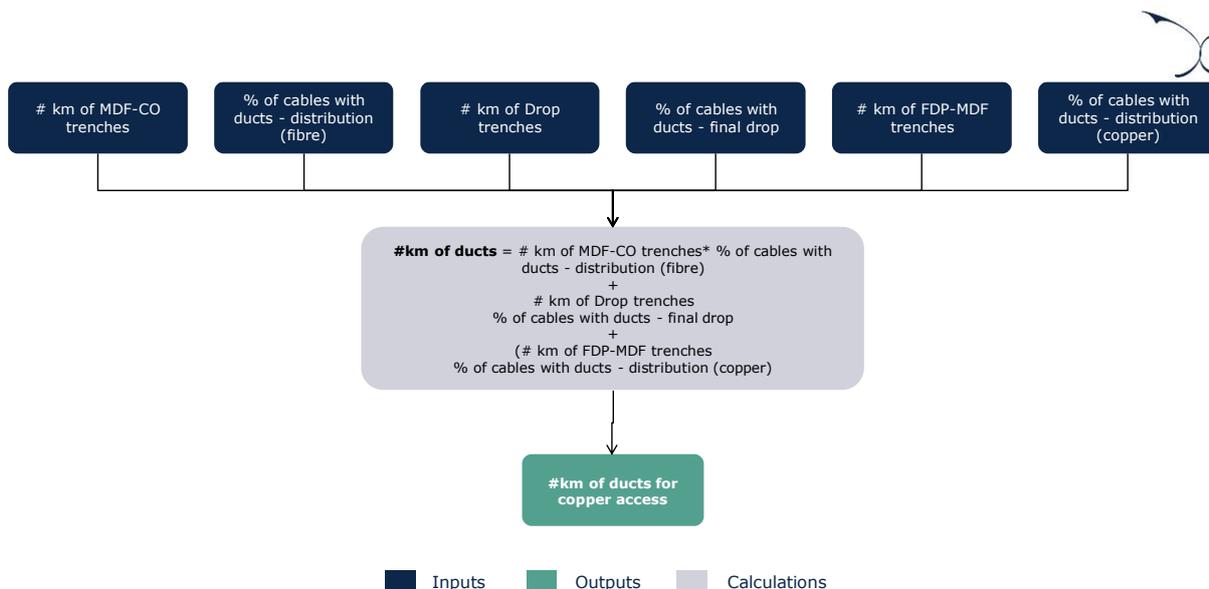


Exhibit 5.22: Calculation of km of ducts in the copper access network [Source: Axon]

Joint holes and Manholes

Finally, the number of Manholes and Joint holes is determined in the model. For that, the model considers the following:

- ▶ One manhole is installed in each DP
- ▶ One joint hole is installed in each joint

5.3.2 Fibre Access Network Dimensioning

The dimensioning algorithm in the model is disaggregated between PON and PTP for practical reasons. However, the algorithms followed in their dimensioning are mostly identical. In this section we present the algorithms for PON and PTP fibre together, highlighting any differences that may exist in the dimensioning of each of these topologies.

The algorithms for fibre access networks are organized into five steps, as shown in the chart below:

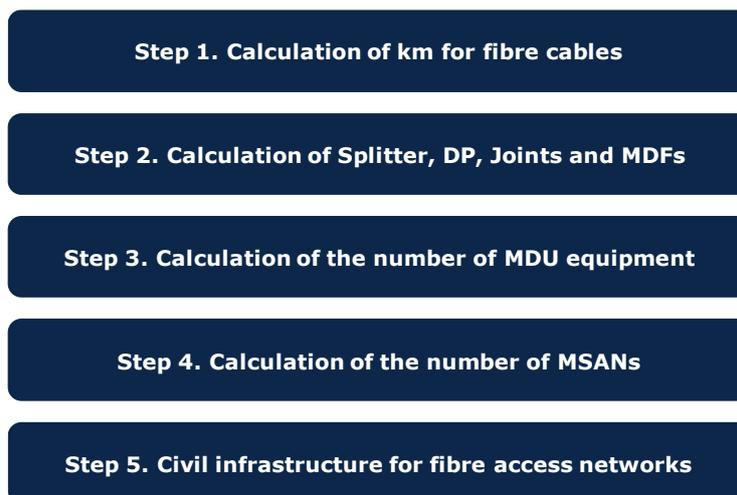


Exhibit 5.23: Steps followed for the dimensioning of fibre network elements [Source: Axon]

The dimensioning algorithm for the fibre access network is implemented in the worksheet '5B DIM GEO' of the model for each one of the geotype. The dimensioning is performed separately for PON and PTP networks, taking into account the drivers and characteristics of each one.

The following subsections provide further detail about each specific step of the algorithm.

Step 1. Calculation of km for fibre cables

The first step in the dimensioning of the fibre access networks consists of the calculation of the number of cables required. The calculation of cables for the fibre access network includes the following calculations:

- ▶ Number of homes connected
- ▶ Final Drop Fibre Cables
- ▶ Fibre cables used between the FDP and CO

The number of such elements is calculated according to the algorithms outlined below.

Number of homes connected

In order to calculate the number of homes connected, the model considers:



- ▶ Number of homes passed in each geotype, considering the number of homes existing in each geotype and the percentage of coverage for each year in each fibre network (see section “4.1 - Coverage” for further details).
- ▶ Percentage of homes passed that are connected (see section “3.9 - Other network and costing inputs” for further details).

The model then considers that one installation is required for each home connected.

Final Drop Fibre Cables

The final drop cables are used in the fibre network to connect the households to their assigned FDP. The fibre drop cables consist of:

- ▶ A Horizontal cable, defined as the direct distance from the house until the side of the street multiplied by a non-optimal factor.
- ▶ A Vertical cable, representing the internal cabling needed to reach each floor for MDU buildings. This also includes the cable from the trench until the ground floor.

Therefore, the total length of drop cables is calculated following the algorithm below:

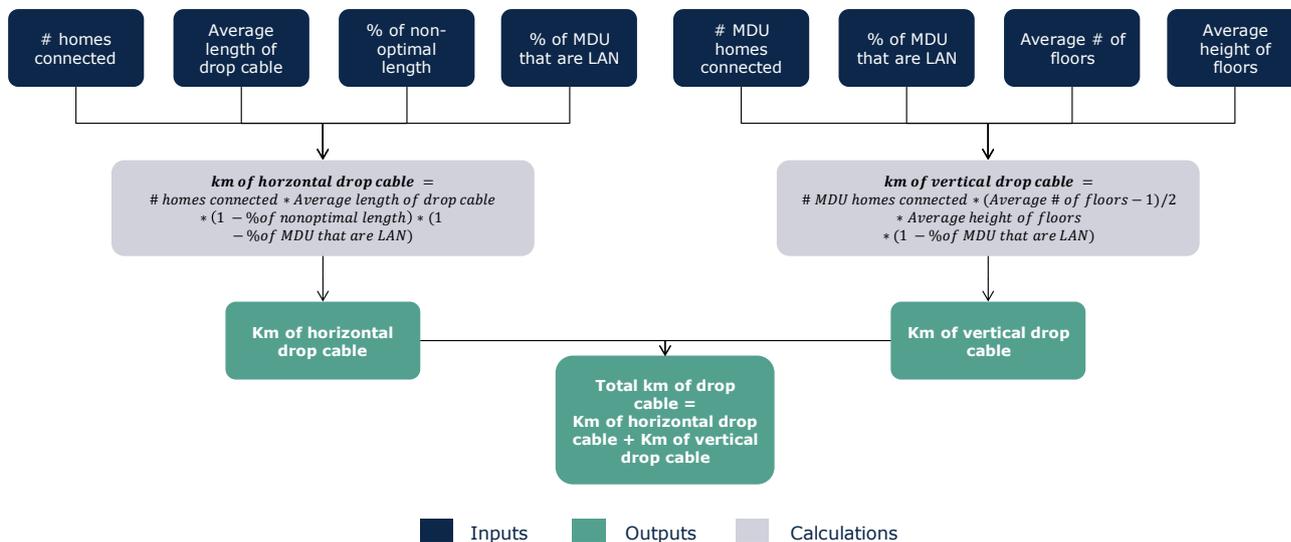


Exhibit 5.24: Calculation of km of fibre drop cable [Source: Axon]



The fibre drop cables are calculated separately for PON and PTP networks. All cables are then adjusted by a factor for excess cable to represent the waste generated during installation.

Fibre cables used between the FDP and CO

The total amount fibre cables used to connect from FDP nodes to CO nodes have been calculated in the R Model, along with the percentage of each configuration of the cable deployed. Therefore, considering this information as input, the kilometres per type of cable have been determined as follows:

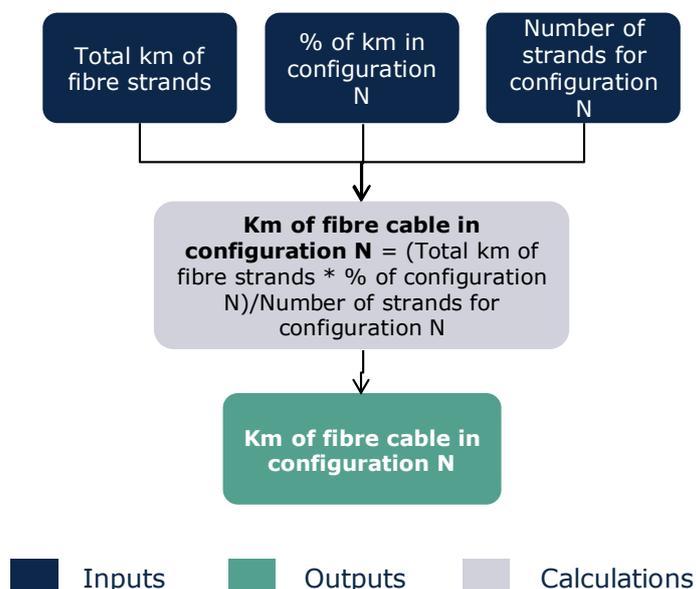


Exhibit 5.25: Calculation of km of fibre cable [Source: Axon]

The N configurations for fibre cables introduced in the model are: 2, 12, 24, 48, 96, 192 strands. All cables are then adjusted by a factor for excess cable to represent the waste generated during installation.



Step 2. Calculation of Fibre splitters, DPs, Joints, and ODFs

The second step focuses on the calculation of the Fibre splitters¹¹, DPs, Joints, and ODFs. The total number of these elements and the percentage of each of their configurations are known (extracted from the outputs of the R Model) and introduced in the Excel model.

The calculation flow is similar for all the elements modelled in this step. The following exhibit presents the algorithm implemented for the DPs:

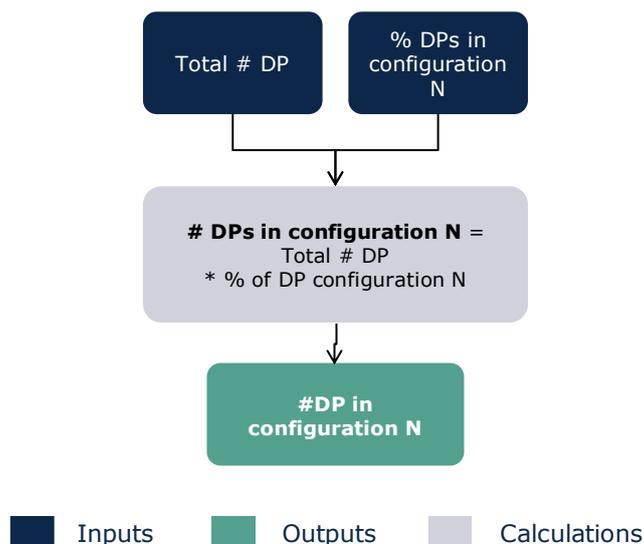


Exhibit 5.26: Calculation of fibre DPs [Source: Axon]

The modelling of the Fibre splitters, ODFs and joints is equivalent to Distribution Points but considering their configurations. The available configurations for each element are presented in the table below:

DP configurations	Fibre Splitters	Joints configurations	MDF configurations
Fibre PDP - out 48 strands	Fibre splitter (1:32)	Fibre joint - 4 strands	ODF - 500 lines
Fibre PDP - out 192 strands		Fibre joint - 12 strands	ODF - 1000 lines
Fibre PDP - out 576 strands		Fibre joint - 24 strands	ODF - 2000 lines
Fibre PDP - out 1152 strands		Fibre joint - 48 strands	ODF - 5000 lines
			ODF - 10000 lines

¹¹ Only for PON fibre.



Exhibit 5.27: Configurations of Fibre splitters, DPs, Joints and ODFs [Source: Axon]

Step 3. Calculation of the number of MDU equipment

The third step presents the calculation of requirements for equipment specific for MDU buildings. This calculation involves the estimation of the number of connected buildings that are MDUs. The algorithm followed to calculate the number of MDU equipment is outlined below:

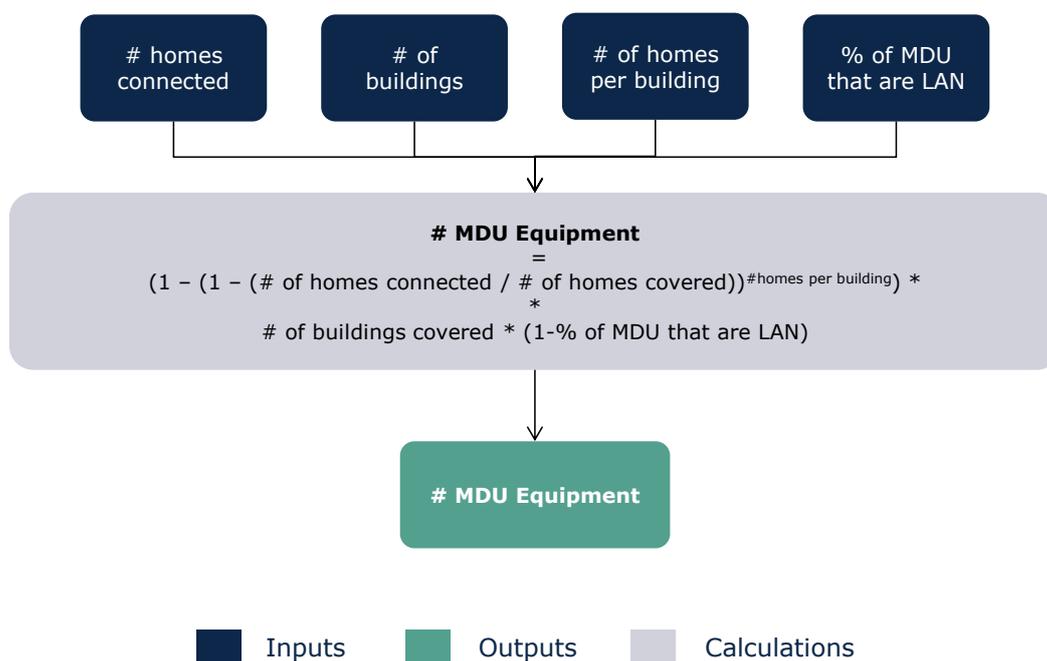


Exhibit 5.28: Calculation of the number of MDU equipment [Source: Axon]

For fibre networks this algorithm is performed separately for PON and PTP networks.

Step 4. Calculation of the number of MSANs and OLTs

Once the previous elements are determined we proceed to calculate the number of MSANs required for the network. The model considers two main types of MSAN depending on their location:

- ▶ OLT: Used for the PON architecture
- ▶ PTP MSAN: Used for the point-to-point architecture



OLTs for PON fibre

The number of PON OLTs can be determined based on two factors:

- ▶ Coverage: The geographical analysis performed in section '4.1 Coverage' determines the number of OLTs required for the actual coverage of the network
- ▶ Demand: the number of OLTs required in order to attend the fibre services demand (active fibre connections). This number is calculated in the Excel model.

Once both numbers are calculated, the highest number of both will be chosen.

Therefore, to determine the final number of OLTs, three main steps have been followed:

1. The minimum number of ports required for the OLTs is set equal to the total number of splitters in the network.
2. The second step calculates the number of cards required in the network attending to the demand and to coverage. The algorithm used is presented below:

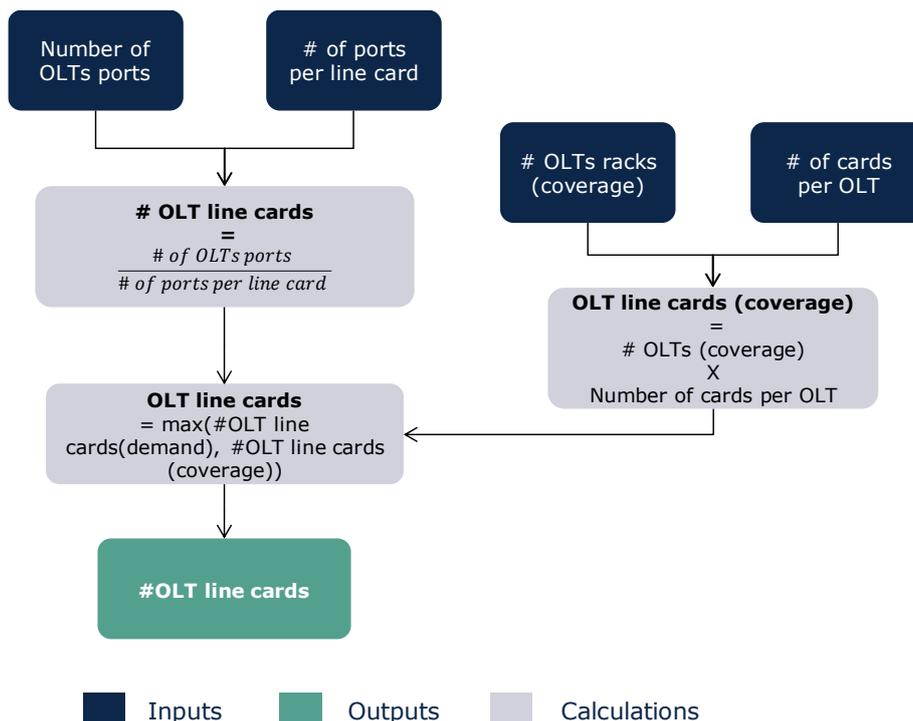


Exhibit 5.29: Calculation of OLT line cards [Source: Axon]



- Given the number of OLT line cards required in the network, the third step proceeds to calculate the number of OLTs needed to handle these line cards, and the number of ports required for the total number of line cards.

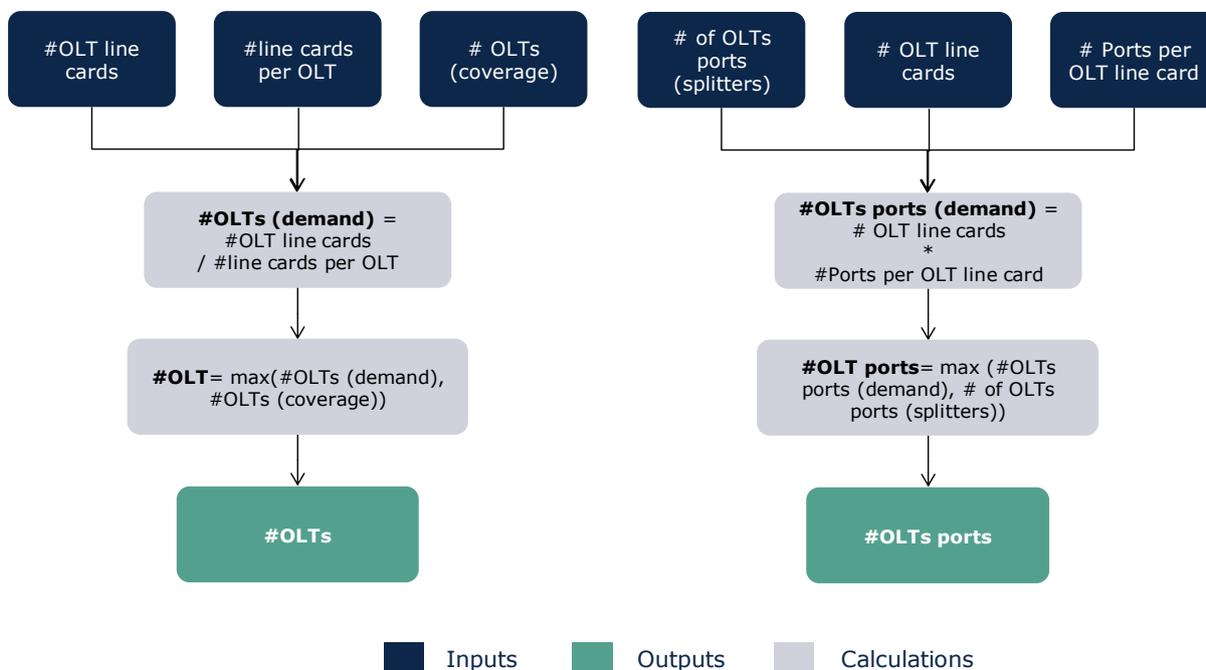


Exhibit 5.30: Calculation of number of OLTs and ports [Source: Axon]

In case the model is executed under the “PTP as PON networks”-option, additional OLTs are dimensioned for the PTP lines migrated to PON.

MSANs for PTP fibre

For the PTP MSANs, the exact same calculation flow has been applied considering the percentage of fibre connections connected through PTP architecture.

Ports for access nodes

These ports are located in the L3 access nodes and are used to connect the fibre PTP MSANs and the OLTs with the core and transmission networks. Therefore, the calculation performed to determine their number follows the steps below:

- Calculation of the broadband traffic per node (PTP MSAN or OLT)

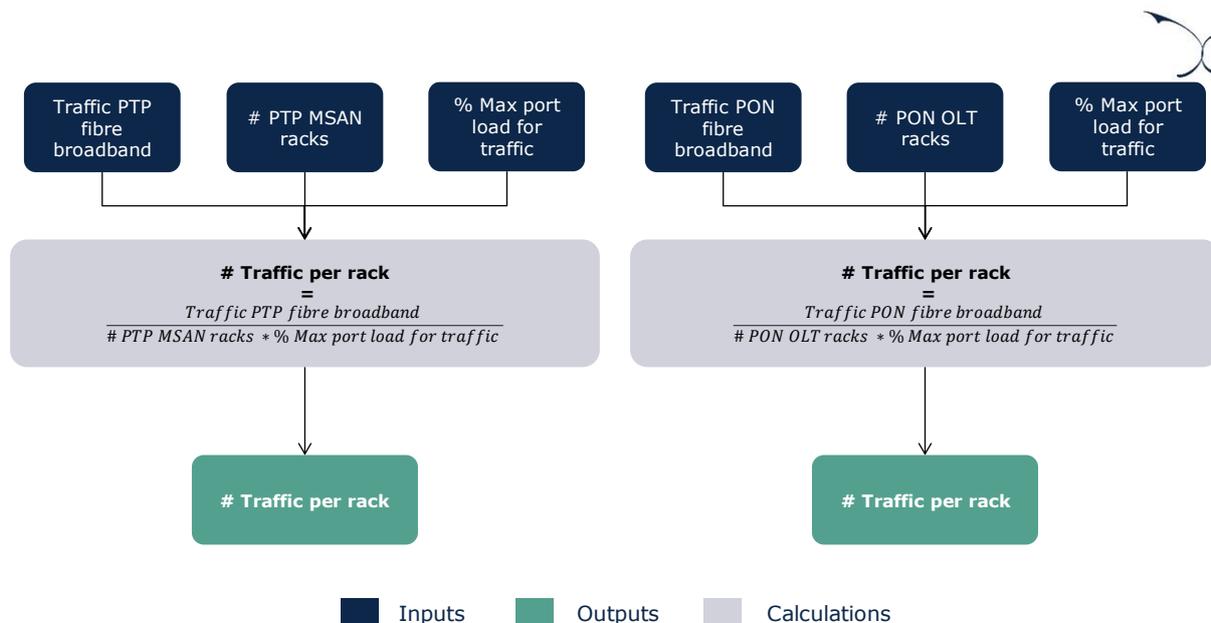


Figure 5.1: Calculation of the number of ports required to connect the access nodes [Source: Axon]

2. Calculation of the number of SFPs ports needed to handle the traffic. The selection of the SFPs is performed so that the port has enough capacity to fulfil the traffic needs of a rack.

Step 5. Civil infrastructure for fibre access networks

The last step is related to the dimensioning of the civil infrastructure required for the fibre access network. The civil infrastructure required for this technology consists of:

- ▶ Home-FDP Trenches: these are the trenches dug for final drop cables
- ▶ Road crossing trenches: trenches dug when there is a need to cross a road.
- ▶ FDP-SDP trenches: required for the buried fibre cables used in this part of the network
- ▶ SDP-CO trenches: required for the buried fibre cables used in this part of the network
- ▶ Ducts
- ▶ Joint holes and manholes

In the following sections, the calculations done in order to determine these elements are presented.



Home-FDP Trenches

The total km of trenches for the final drop cables are calculated using the following algorithm:

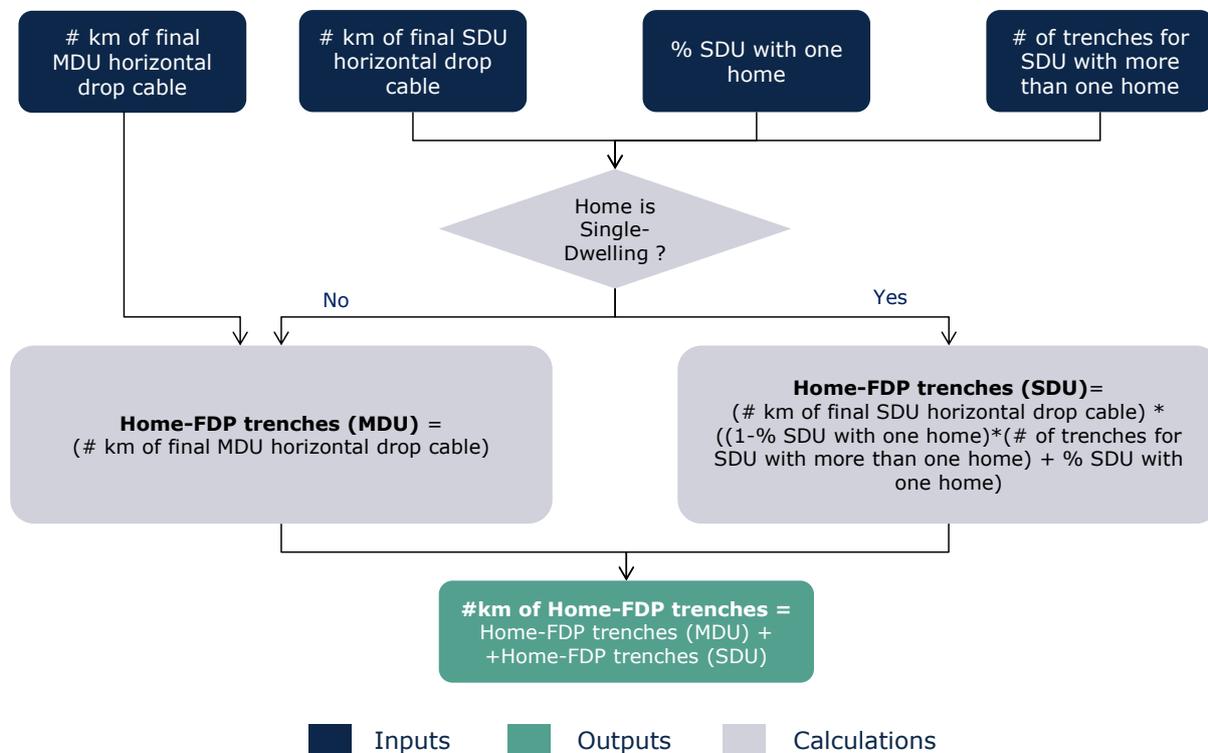


Exhibit 5.31: Calculation of Home-FDP Trenches [Source: Axon]

Road crossing trenches

In addition, the model includes the trenches related to the road crossings that are extracted from the geographical analysis.

FDP-SDP trenches

The geographical analysis allows for the calculation of the total length of trenches required for the fibre access network. However, this total distance contemplates the hypothetical case where there is no sharing of these trenches. In actuality, the trenches could be shared with other access technologies, the core network or even utility companies.



In this section we present the adjustments done in order to settle the number of km that are used exclusively for access networks, distinguishing the part that is shared with transmission and core networks.

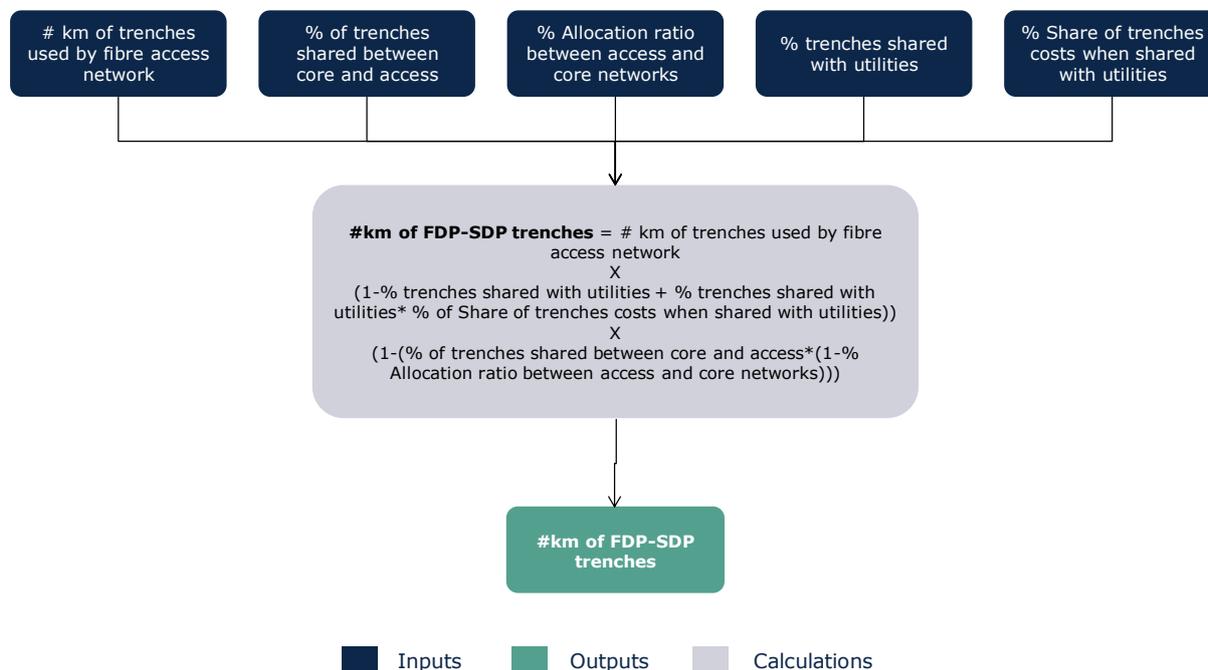


Exhibit 5.32: Calculation of FDP-SDP Trenches [Source: Axon]

SDP-CO trenches

The geographical analysis allowed the calculation of the total length of trenches required for the SDP-CO connections for the fibre access network. As for the FDP-SDP trenches, this part of the network can also be shared. In order to consider this sharing, the same algorithm as for FDP-SDP trenches has been followed.

Ducts

The calculation for km of ducts follows the algorithm below:

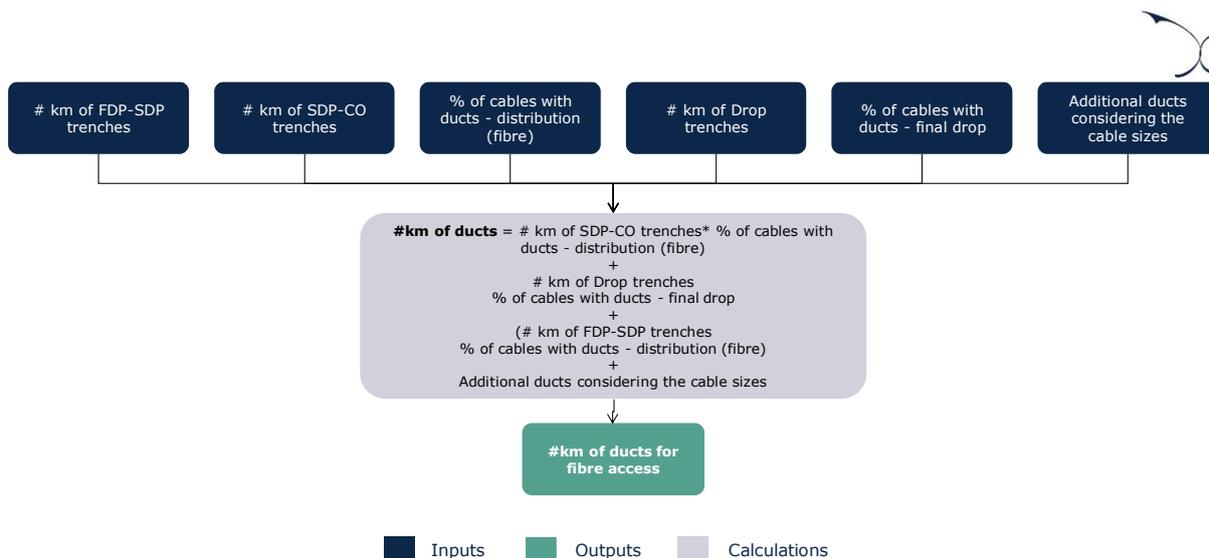


Exhibit 5.33: Calculation of Ducts [Source: Axon]

In the case that ducts are necessary for drop trenches; the model will consider the size of the cables necessary for the homes. If the size of the necessary cables is larger than the space available inside of a duct (for instance, in the case of large apartment buildings), additional ducts will be considered.

Joint holes and manholes

Finally, the number of manholes and joint holes is determined in the model. For that, the model considers the following:

- ▶ No manholes are installed in the fibre networks, given that the distribution points are commonly placed above ground in cabinets. This came into light after discussions with the operators during the 3rd consultation round.
- ▶ Similarly, based on the comments provided by the operators during the preparation of the model after the 3rd consultation, joint holes are only installed for joints equal or bigger than 24 strands.

5.3.3 Coax Access Network Dimensioning

The dimensioning algorithm for the coax access networks is organized into three steps, as shown in the chart below:

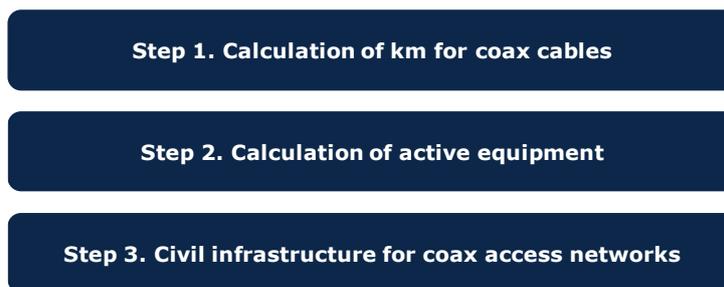


Exhibit 5.34: Steps followed for the dimensioning of coax network elements [Source: Axon]

The dimensioning algorithm for the coax access network is implemented in the worksheet '5B DIM GEO' of the model for each of the geotypes. The following subsections provide further detail about each specific step of the algorithm.

Step 1. Calculation of km for coax cables

The first step in the dimensioning of the coax access network consists of the calculation of the number of cables required. Like the copper network, the coax access network is composed of three main types of cables:

- ▶ Final Drop Coax Cables
- ▶ Coax cables used for distribution (TAP-CMC)
- ▶ Fibre cables used between the CMC and CO

The number of such elements is calculated according to the algorithms outlined below:

Final drop coax cables

The final drop cables are used in the coax network to connect the households to their assigned TAP. The coax drop cables consist of:

- ▶ A Horizontal cable, defined as the direct distance from the house until the side of the street multiplied by a non-optimal factor. In the case that the model is run without considering digging in private properties, then this parameter is not estimated.
- ▶ A Vertical cable, representing the internal cabling needed to reach each floor for MDU buildings. This also includes the cable from the trench until the ground floor.

Therefore, the total length of drop cables is calculated following the algorithm below:

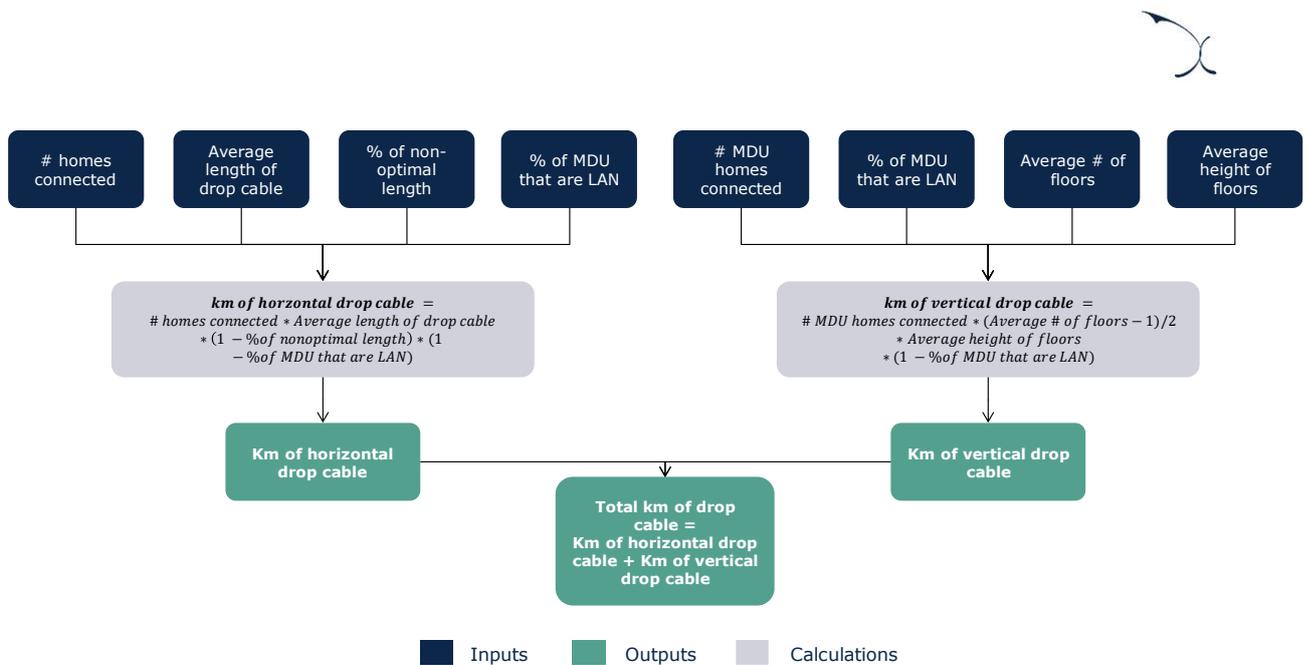


Exhibit 5.35: Calculation of km of fibre drop cable [Source: Axon]

All cables are then adjusted by a factor for excess cables to represent the waste generated during installation.

Coax cables used for distribution (TAP-CMC)

The total distance of coax cables used to connect TAP nodes to CMC nodes have been calculated in the R Model. As there is only one type of coax cables used for this section of the network, this number has been attributed fully to the resource of "Coax cables used for distribution (TAP-CMC)". All cables are then adjusted by a factor for excess cable to represent the waste generated during installation.

Fibre cables used between the CMC and CO

The total distance of fibre cables used to connect the CMCs to the COs in the Coax Access network have been determined in the geographical analysis. This cable has only one possible configuration (12 strands), and therefore the result from the geographical analysis is directly entered for this resource. All cables are then adjusted by a factor for excess cable to represent the waste generated during installation.



Step 2. Calculation of active equipment

The second step focuses on the calculation of the active equipment required for the coax access network. The active equipment dimensioned is:

- ▶ Coaxial amplifier
- ▶ Splitters
- ▶ TAP, CMC, OLT
- ▶ Cabinets

Coaxial amplifier

The coaxial amplifiers are used to boost/amplify the coax signal in order to improve the quality of service for end-users.

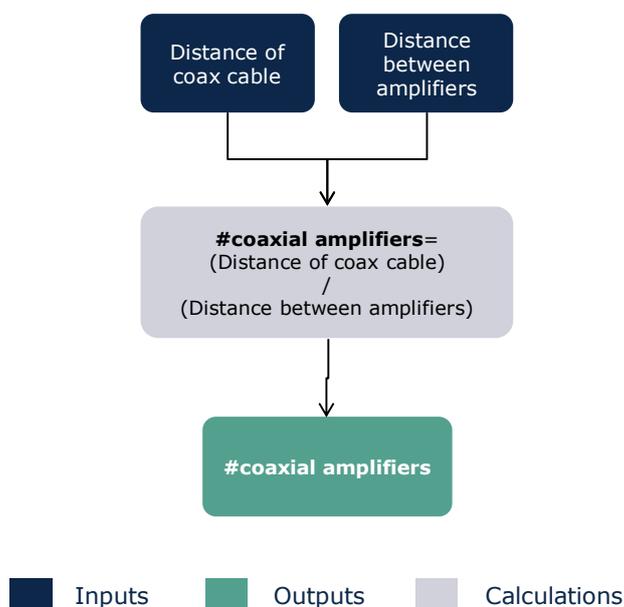


Exhibit 5.36: Calculation of number of Coaxial Amplifiers [Source: Axon]

Splitters, TAP, CMC and OLT

The number of splitters, TAPs, CMCs and OLTs has been determined in R Model, and the results are introduced in the Excel model for the respective resources.



Ports for access nodes

These ports are located in the L3 access nodes and are used to connect the coax OLTs with the core and transmission networks. Therefore, the calculation performed to determine their number follows the steps below:

1. Calculation of the broadband traffic per node (OLT)

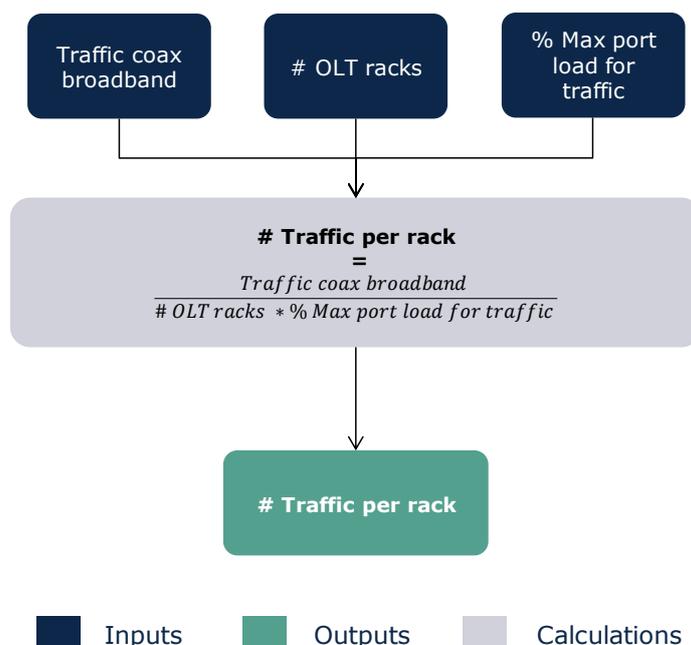


Figure 5.2: Calculation of the number of ports required to connect the access nodes [Source: Axon]

Calculation of the number of SFPs ports needed to handle the traffic. The selection of the SFPs is performed selecting the most cost-efficient solution. The algorithm followed for this is presented in the section '5.2. Transmission network dimensioning'.

Cabinets

The model includes two types of cabinets (small and large). The small cabinets are used for the Coaxial amplifiers whilst the large ones are installed for the CMC. Therefore, the calculation of these elements follows the principles below:

- ▶ A small cabinet is installed for each Coaxial Amplifier and Coaxial DP
- ▶ A large cabinet is installed for each CMC



MDU equipment

The third step presents the calculation of requirements for equipment specific for MDU buildings. This calculation involves the estimation of the number of connected buildings that are MDUs. The algorithm followed to calculate the number of MDU equipment is outlined below:

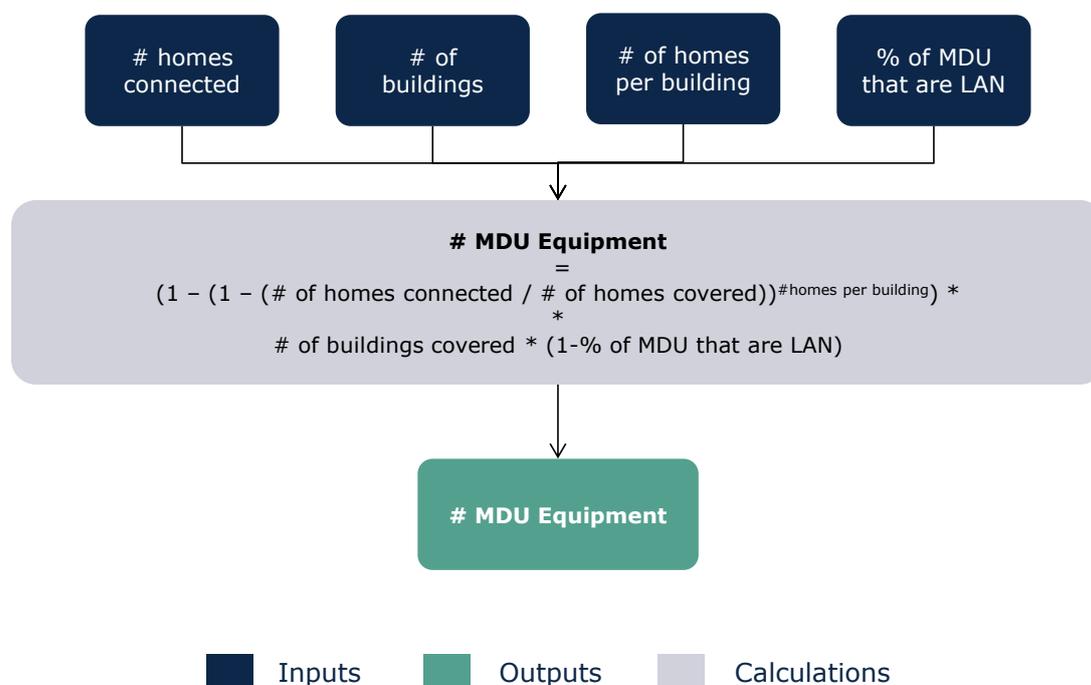


Exhibit 5.37: Calculation of the number of MDU equipment [Source: Axon]

Step 3. Civil infrastructure for coax access networks

The last step is related to the dimensioning of the civil infrastructure required for the coax access network. The civil infrastructure required for this technology consists of:

- ▶ Home-TAP trenches: these are the trenches dug for final drop cables
- ▶ Road crossing trenches: trenches dug when there is a need to cross a road.
- ▶ TAP-CMC trenches: required for the buried coax cables used in this part of the network
- ▶ CMC-CO trenches: required for the buried fibre cables used in this part of the network
- ▶ Ducts
- ▶ Joint holes and Manholes



In the following sections, the calculations done in order to determine these elements are presented.

Home-TAP Trenches

The total km of trenches for the final drop cables are calculated using the following algorithm:

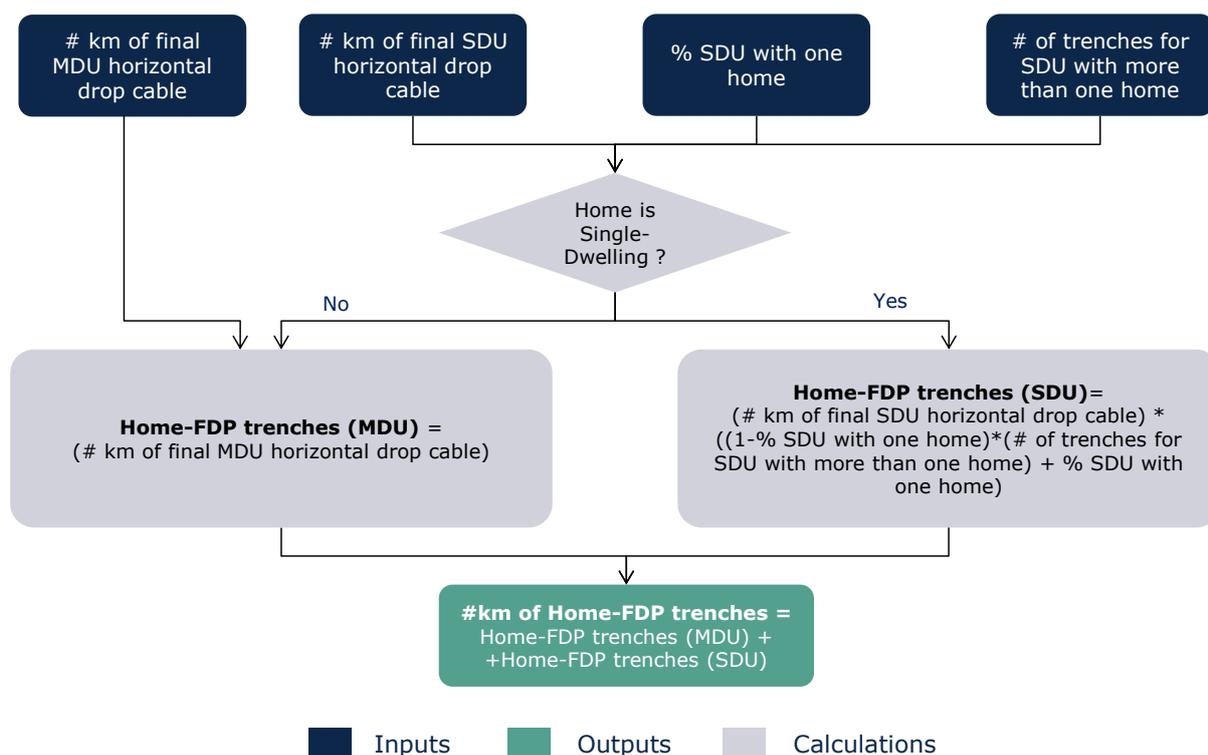


Exhibit 5.38: Calculation of Home-TAP Trenches [Source: Axon]

Road crossing trenches

In addition, the model includes the trenches related to the road crossings that are extracted from the geographical analysis.

TAP-CMC trenches

The geographical analysis allows the calculation of the total length of trenches required for the coax access network. However, this total distance contemplates the hypothetical case where there is no sharing of trenches. In actuality, the trenches could be shared with other access technologies, the core network or even utility companies.



In this section we present the adjustments done in order to settle the number of km that are used exclusively for access networks, distinguishing the part that is shared with transmission and core networks.

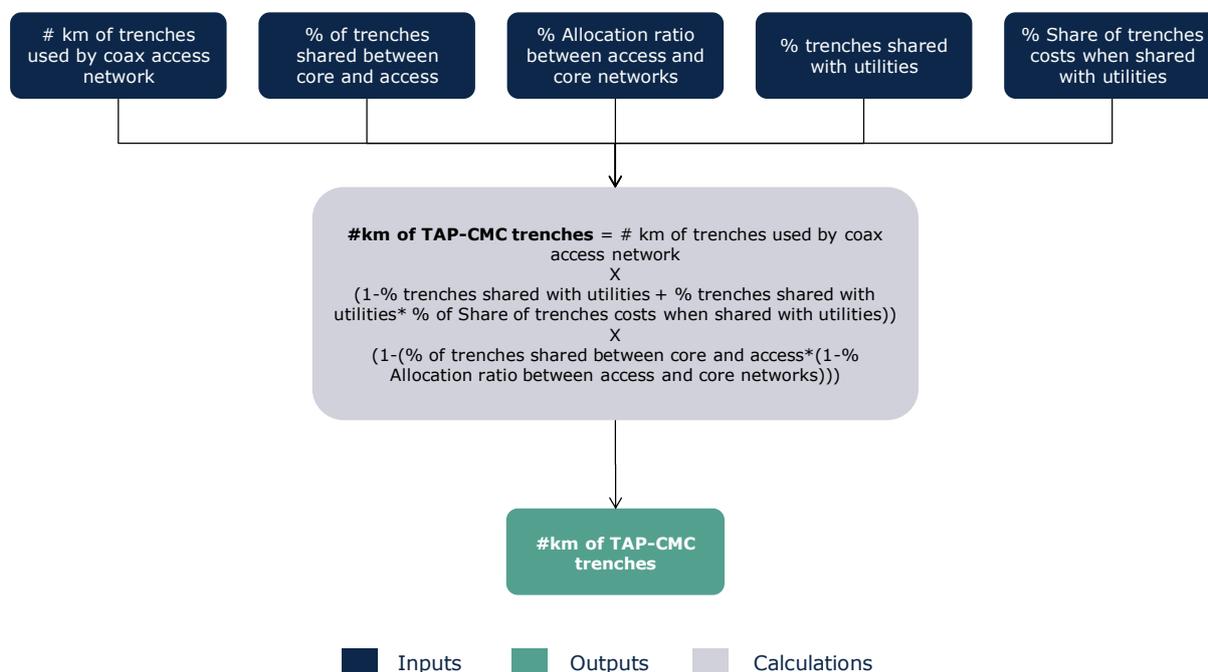


Exhibit 5.39: Calculation of TAP-CMC trenches [Source: Axon]

CMC-CO trenches

The geographical analysis allowed the calculation of the total trenches required for the CMC-CO connections for the coax access network. As for the TAP-CMC trenches, this part of the network can also be shared. In order to consider this sharing, the same process as for TAP-CMC trenches has been followed.

Ducts

Part of the cables of the coax network is introduced in ducts. Hence, the calculation of km of ducts follows the algorithm below:

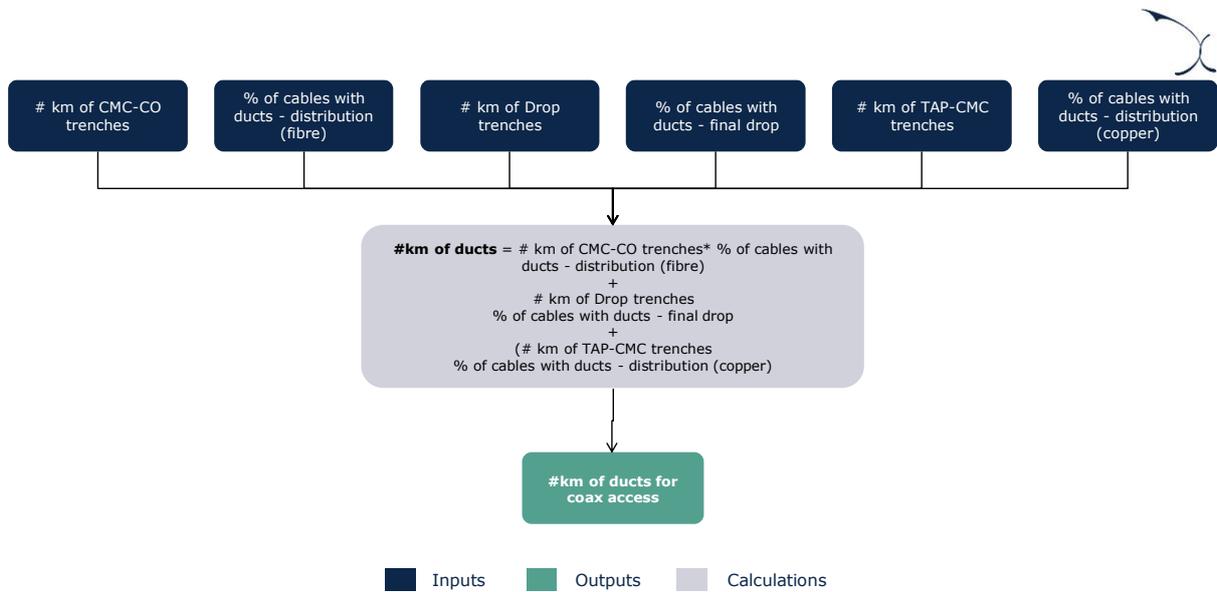


Exhibit 5.40: Calculation of ducts for the coax access network [Source: Axon]

Joint holes and Manholes

Finally, the number of manholes and joints holes is determined in the model. For that, the model considers the following:

- ▶ One manhole is installed in each Coaxial amplifier and Splitter
- ▶ One joint hole is installed in each TAP



6. Resources costing

Once the model has calculated the number of resources needed to accommodate the demand and coverage levels in the network, the next step is to calculate the costs of the network. This calculation is performed separately for CapEx and OpEx on a nation-wide aggregated level.

The procedure to assess network costs is presented in the following sections

- ▶ Calculation of network costs
- ▶ Calculation of non-network costs

6.1. Calculation of network costs

Two main steps are followed to calculate total network annual costs (including both CapEx and OpEx):

Step 1. Determination of unit costs throughout the modelling period

Step 2. Calculation of annual network costs

Exhibit 6.1: Resources Costing [Source: Axon]

The following sections explain each step in detail.

Step 1: Determination of unit costs throughout the modelling period

The definition of the unit costs is performed separately for CapEx and OpEx components.

Notably, for the definition of the CapEx unit costs of the resources considered in the model, the following formula is considered:

$$Unit\ CapEx_i(n) = Unit\ CapEx_{2018}(n) * (1 + t(n))^{(i-2018)}$$

Where:

- ▶ **Unit CapEx_i (n)**: Represents the cost of installing and acquiring a unit of network element "n" in the year "i". The figure included for the reference year (2018) is input in the model based on the process



- ▶ **t (n):** For each resource, a cost trend can be introduced, outlining the expected evolution of its prices in the future period.

Meanwhile, for the determination of the unit costs of the resources considered in the model, the following formula is considered:

$$Unit\ OpEx_i(n) = Unit\ CapEx_{2018}(n) \cdot \% \text{ of } OpEx(n) \cdot CPI_i \cdot ((1 - m(n)) + \frac{m(n)}{PI_i})$$

Where:

- ▶ **Unit CapEx_i (n):** Represents the cost of installing and acquiring a unit of network element "n" in the year "i". The figure included for the reference year (2018) is input in the model based on the process
- ▶ **% of OpEx (n):** represents the measure of OpEx as a percentage of the unit CapEx.
- ▶ **CPI_i:** Represents the index of inflation in Denmark for the year "i" referenced to 2018.
- ▶ **m (n):** Represents the percentage of unit OpEx that is related to man-work for network element "m".
- ▶ **PI_i:** Represents the productivity index, used to evaluate the improvement in the amount of man-work that can be done in the same time in year "i" compared to 2018.

The definition of each of these inputs is presented detailed in section '3.2 - Asset costs' of this document.

Step 2. Calculation of annual network costs

Once the unit costs for each resource and year are determined, the calculation of annual costs is calculated.

The calculation of annual costs relies on the use of a given methodology to depreciate capital costs. The model defines two alternatives:

- ▶ Tilted annuities
- ▶ Economic depreciation

The implementation followed in the model to calculate total annual costs (considering both, CapEx and OpEx) is presented below.



Tilted annuities

The tilted annuities approach aims to adapt the profile of cost recovery with the objective of recognizing fluctuations in asset prices. For example, in case prices of assets decrease, a new market entrant could have a great advantage over existing operators because it will benefit from better prices and therefore lower depreciation costs. Following this tilted annuity approach, when prices decrease, a higher proportion of the asset is recovered during the initial periods so the same cost will be recognized for both market participants, not taking into account the time when they entered the market.

The formula used in the model to obtain the annualized capital-related expenses is presented below:

$$A_t = I \times \frac{(\omega - p) \times (1 + p)^t}{1 - \left(\frac{1 + p}{1 + \omega}\right)^n}$$

Where ω is the cost of capital, I the investment, t the year considered, n the asset life, p the tilt (price trend of the asset in the long term) and A_t the annuity of year t ¹². This formula is derived by the same equation as the one provided at the beginning of this section¹³ but with the following relationship between each annuity:

$$A_t = A_{t-1} \times (1 + p)$$

Which means that annuities are evolving with asset prices.

In this case, annual OpEx is considered separately, following a P·Q approach based on the unit costs of the resources calculated in Step 1 and the number of resources outputted from the dimensioning algorithms.

¹² This annuity is calculated by assuming that the first annual cost recovery is occurring one year after the investment is made. If the time between the moment the first annuity happens, and the investment is paid is one year lower (respectively one year higher), then the annuity should be multiplied by a $(1 + \omega)^{-1}$ (respectively $(1 + \omega)$).

¹³ $I = \sum_{i=1}^n \frac{A_i}{(1+\omega)^i}$



Economic depreciation

The objective of economic depreciation is to adjust the recovery of the asset value to the economic value it produces.

In particular, economic depreciation adjusts the annuities of the investment by means of a production factor, defined by the performance that is extracted from the asset. For instance, if an asset is expected to be used more exhaustively in the future (e. g. due to an increase in adoption), the application of the economic depreciation results in higher annuities in the future than in the present (and relatively constant unitary costs).

Particularly, the formula used in the calculation for the economic depreciation is as follows:

$$A_t = O_t \times p_t \times \frac{\sum_{j=1}^n (1 + \omega)^j \times I_j}{\sum_{j=1}^n (1 + \omega)^j \times O_j \times p_j}$$

Where,

- ▶ A_t represents the annual cost
- ▶ O_t is the production factor of the asset in year t
- ▶ p_t is the reference price of the asset in year t
- ▶ ω represents the cost of capital
- ▶ I_j represents the yearly investment, calculated as the number of assets purchased in year j multiplied by their unit price in that year. This figure shall accrue the OpEx that would be incurred in order to operate and maintain the asset throughout its lifetime.
- ▶ N represents the last year in which an asset is used in the network.

As extracted from above, in the case that economic depreciation is considered, OpEx is not treated separately.

6.2. Calculation of non-network costs

The model also considers the costs not related to the network. This type of cost is included in the model as a mark-up over total network costs (considering, both, CapEx and OpEx). The figures have been calculated based on data from the modelled operator. Notably, the total network costs have been extracted from the Accounting Separation results, as the



sum of depreciation and OpEx of all products, excluding those related to voice and mobile and excluding support/overhead (non-network) expenditures.

As presented in section '3.7 - Non-network overheads', there are 4 different mark-ups depending on the nature of the costs:

- ▶ G&A mark-up
- ▶ IT mark-up
- ▶ Wholesale and commercial mark-up
- ▶ Working capital mark-up

These mark-ups are applied to the total network costs (including CapEx and OpEx) to calculate the total non-network costs borne by the modelled operator. These costs are then allocated to services following the approach described in section '7.2.3 - Step 3: Cost Allocation to Services'.



7. Network costs of the services

This section presents the methodology followed to calculate the incremental and common costs of the resources, and how these costs will be allocated to the services in order to obtain unit costs under the LRAIC standard.

7.1. Incremental and common costs calculation

The incremental cost associated with each increment is the reduction in the costs calculated by the model due to ceasing the provision of the services included in that increment. This cost is expressed mathematically as the difference between the cost of total demand and the cost obtained when the level of demand for the services included in the increment is set to zero, leaving all others unchanged:

$$INCREMENTAL\ COST(increment1) = F(v1, v2, v3, vN, C) - F(0, v2, v3, vN, C)$$

Where F is the formula that represents the LRAIC model (which calculates the cost according to demand and coverage), v_i represents the demand volume of increment i , and C represents the coverage.

To calculate the incremental costs, increments are defined as groups of services. Therefore, services have to be assigned to increments. In the model (sheet 'OF PAR OTHER'), one increment has been defined, related to the Demand of all the services modelled.

Once incremental costs are calculated for this increment, as described previously, common costs by the resource are obtained as the difference between the total cost base obtained under Fully Allocated Costs standard (considering all the demand) and the incremental costs. The following formula shows this calculation:

$$COMMON\ COST = TOTAL\ COSTS\ (Fully\ Allocated\ Costs) \\ -\ INCREMENTAL\ COST(Demand\ increment)$$

In the model, resources' incremental and common costs are calculated in sheet '6E RES INCR-COM COST'.



The following section presents the methodology employed for the allocation of resources' costs to services in the model.

7.2. Allocation of network costs to services

Incremental costs are allocated to services using Routing Factors. This methodology allocates costs to services based on their usage of each equipment. The Routing Factor is a measure of how many times a resource is used by a specific service during its provision. Once annual costs incurred per resource are available, these have to be distributed to the final services.

The allocation of network costs is performed at geotype level. This is done to ensure causality in the allocation of the costs, given that the demand and costs for each geotype follow different patterns.

The steps followed in the allocation process are depicted below:

- ▶ Step 1: Mapping of services and resources
- ▶ Step 2: Calculation of demand for the three allocation criteria
- ▶ Step 3: Cost Allocation to Services

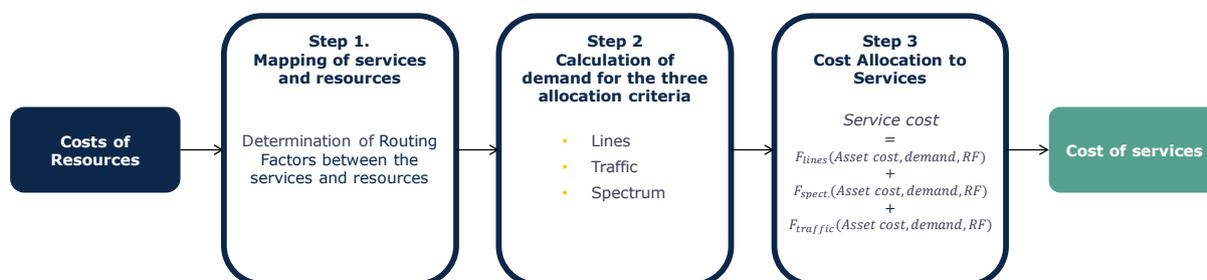


Exhibit 7.1: Cost imputation process using Routing Factors [Source: Axon]

As common costs are allocated to services based on an Effective Capacity approach, this approach is followed to allocate both incremental and common costs to services.



7.2.1 Step 1: Mapping of services and resources

Resources' costs have to be allocated to the services proportionally to the amount of lines/traffic/spectrum they generate/use and to a "factor of use", the Routing Factor. Hence, the more lines/traffic/spectrum a service generates/uses, the higher the cost will be allocated to it from the asset considered.

The excerpt below illustrates some relationships between resource and services, together with the applicable routing factor:

Service	Access fibre.Fibre drop cable.length	Access fibre.Fibre cable - 2 strands (SDP-User).length	Access fibre.Fibre cable - 12 strands (SDP-User).length	Access fibre.Fibre cable - 24 strands (SDP-User).length	Access fibre.Fibre cable - 48 strands (SDP-User).length	Access fibre.Fibre cable - 96 strands (SDP-User).length	Access fibre.Fibre cable - 192 strands (SDP-User).length
Access.Fibre.Retail.Access	1	1	1	1	1	1	1
Access.Fibre.Wholesale.Raw access (POI0)	1	1	1	1	1	1	1
Access.Fibre.Wholesale.Raw access (POI1)	1	1	1	1	1	1	1
Access.Fibre.Wholesale.VULA access (POI1)	1	1	1	1	1	1	1
Access.Fibre.Wholesale.BSA Access (POI2/POI3)	1	1	1	1	1	1	1

Exhibit 7.2: Illustrative extract of the routing factors defined between services and resources (Sheet '3C MAT ROUTING FACTORS') [Source: Axon]

7.2.2 Step 2. Calculation of demand for the three allocation criteria

The cost imputation process is done depending on the resources' nature. Notably, the resources introduced in the model can be divided into three main groups based on the driver shaping the allocation of its cost:

- ▶ **Lines**, these are network elements that rely on the number of lines of the service to allocate the proper amount of costs. These include, for instance, all passive elements in the access network.
- ▶ **Traffic**, these are network elements that rely on the volume of traffic of the service to allocate the proper amount of costs. These include, for instance, the ports in the routers in the transmission network.
- ▶ **Spectrum**, these are network elements that rely on the spectrum (in MHz) used by the service to allocate the proper amount of costs. The elements needing this allocation methodology are in the coax access network, where some elements allocate the spectrum to TV or broadband services.

To perform an accurate allocation of the services, based on the three criteria, the demand of the services has to be transformed into these three main groups. To perform this



transformation, the demand of the services introduced in the model is multiplied by a series of factors or weights depending on the relevant allocation driver.

7.2.3 Step 3: Cost Allocation to Services

Once the relationship of each service to each resource has been performed (Step 1) and ensuring that the demand allocation driver is properly analysed in the relevant unit (Step 2), it is possible to distribute all costs to all services.

This step is performed separately for each of the allocation criteria presented in Step 2 and for each geotype independently. The basic relation is the following:

$$\begin{aligned}
 & \text{Service cost}(i, \text{year}) \\
 &= \sum_n \frac{\text{Cost}_{\text{lines}}(n, \text{year}) \cdot \text{Demand}_{\text{lines}}(i, \text{year}) \cdot \text{RF}(i, n)}{\sum_i \text{Demand}_{\text{lines}}(i, \text{year}) \cdot \text{RF}(i, n)} \\
 &+ \sum_n \frac{\text{Cost}_{\text{traffic}}(n, \text{year}) \cdot \text{Demand}_{\text{traffic}}(i, \text{year}) \cdot \text{RF}(i, n)}{\sum_i \text{Demand}_{\text{traffic}}(i, \text{year}) \cdot \text{RF}(i, n)} \\
 &+ \sum_n \frac{\text{Cost}_{\text{spectrum}}(n, \text{year}) \cdot \text{Demand}_{\text{spectrum}}(i, \text{year}) \cdot \text{RF}(i, n)}{\sum_i \text{Demand}_{\text{spectrum}}(i, \text{year}) \cdot \text{RF}(i, n)} +
 \end{aligned}$$

Where:

- ▶ Service cost (i, year) is the cost of service "i" in a given year
- ▶ Cost (n, year) is the cost of resource "n" in a given year. Assets are separated based on their specific rule for allocation (demand, traffic and spectrum).
- ▶ Demand (i, year) is the demand of the service "i" in the selected year. As for assets, the demand considered depends on the allocation rule of the associated asset.
- ▶ RF (i, n) is the Routing Factor that relates the resource "n" with service "i".

The allocation of resources' cost to services is presented in the sheet '7C GEO SERV COSTS' and where the formula used allows the implementation of steps described under this section.

It should be noted that common and joint network costs are also allocated to services based on this methodology, aligned with the "effective capacity" approach defined in the MRP.



On the other hand, the non-network overheads determined in section '3.7 Non-network overheads' are distributed to the different services following an equi-proportional mark-up (EPMU) approach.



Annex A. User manual for the Excel model

This section provides guidelines on how to use the Excel model, and is divided among the following sub-sections:

- ▶ **Getting started**, providing a set of high-level specs related to the hardware required to run the model.
- ▶ **General overview of the model**, describing the structure and worksheets of the Excel model.
- ▶ **Understanding the control panel**, presenting the Control Panel of the Excel model, which is the main user interface where the main options and scenarios are selected. Additionally, this worksheet contains a 'RUN' button to execute the Excel model.
- ▶ **Description of checks**, explaining the meaning of the checks included in the model.

A.1. Getting started

To run the Excel model, a computer with at least 1 GB of RAM memory and with Microsoft Excel version 2010 (or a newer version) is required. For enhanced performance, it is recommended to run the model on computers with at least 2 GB of RAM memory.

A.2. General overview of the model

The Excel model is comprised of worksheets that are grouped in the following blocks or calculation steps:

- ▶ Support and control worksheets
- ▶ Step 0: Parameters
- ▶ Step 1: Main inputs
- ▶ Step 2: Advanced inputs
- ▶ Step 3: Mapping
- ▶ Step 4: Drivers and demand factors
- ▶ Step 5: Dimensioning of the network
- ▶ Step 6: Resource Costing
- ▶ Step 7: Allocation of costs



▶ Step 8: Results

The Excel model has been developed based on a linear architecture in order to improve the execution performance and to ease the understanding of its calculation flow. The exhibit below shows the model calculation flow:

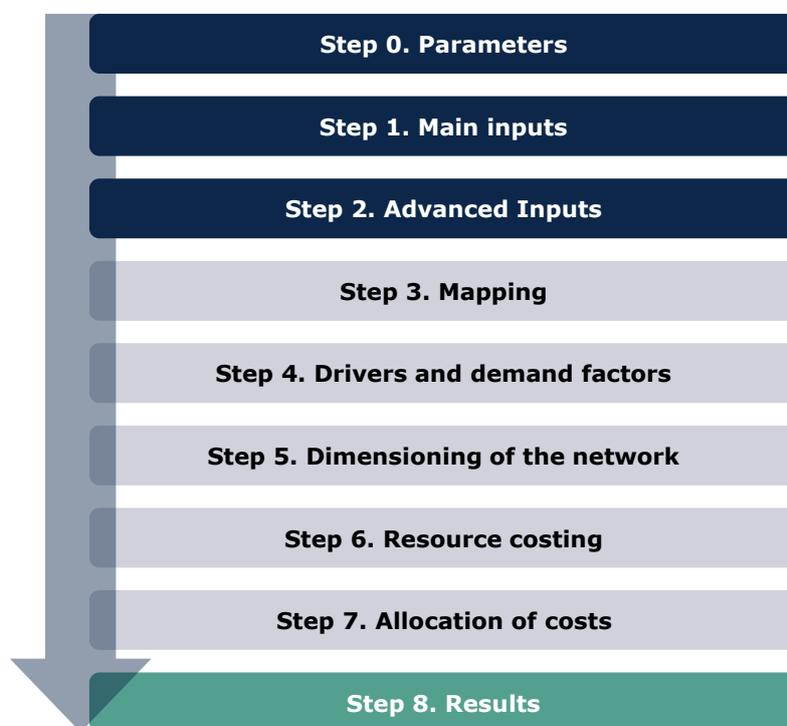


Exhibit 7.3: Calculation flow of the model [Source: Axon]

The block “Support and Control Worksheets” has not been included in the exhibit above for sake of clarity purposes.

The worksheets contained in the blocks or calculation steps have been labelled according to the following structure (except for the “Support and Control Worksheets” block):

- ▶ Step number and ordinal: It is composed of the number of the step (i.e. 0, 1, 2...) and the order in letter format (i.e. A, B ...).
- ▶ Type of worksheet indicators:
 - PAR: Definition of parameters
 - INP: Input worksheet
 - MAT: Matrix obtaining the relationship between two dimensions



- MAP: Mapping between two dimensions
- DIM: Dimensioning of network elements
- RES: Summary of the number and costs of the resources in the network
- GEO: Summary of costs disaggregated at geotype level
- RESULTS: Results worksheets

▶ Name of the worksheet

As an example, the worksheet '1A INP DEMAND' is the first (A) worksheet of the Step 1. It represents an input (INP) related with the demand (DEMAND).

The following sections describe the calculation blocks, including a detailed description of the worksheets contained in each block. It should be pointed out that sub-section 'A.2.1-Support and control worksheets' does not strictly describe a block of the calculation flow, but the supporting and control worksheets used within the model.

A.2.1. Support and control worksheets

The support and control worksheets provide general information to understand and run the model, as well as a number of checks to verify that the model is working properly.

Sheet name	Description
CONTENTS	<ul style="list-style-type: none">▶ Provides high-level information about the model file (i.e. version, status and contacts)▶ Provides a list and description of the model's worksheets
COVER	<ul style="list-style-type: none">▶ This worksheet includes the main modelling options that may be adjusted to execute the model (e.g. WACC, execution mode, annualization methodology). At the same time, it includes the controls for the execution of the model.
MAP	<ul style="list-style-type: none">▶ Map that represents the relationship between the model's worksheet blocks as well as the overall calculation flow.▶ Colours have no meaning and have been selected to ease the identification of the blocks.
COLOUR CODE	<ul style="list-style-type: none">▶ It contains the colour code used throughout the model.
CHECKS	<ul style="list-style-type: none">▶ Multiple checks are performed in this worksheet to ensure that the model is working properly. Further details on these are provided in section 'A.4 - Description of checks' of this document.

Exhibit 7.4: Support and control worksheets. [Source: Axon]



A.2.2. Step 0: Parameters

The worksheets concerning the parameterisations defined in the Excel model are described in the table below:

Sheet name	Description
0A PAR SERVICES	<ul style="list-style-type: none">▶ The list of services (recurring and non-recurring) considered in the model is introduced in this worksheet.▶ Services are defined by the type of service, the customer segment, the allocation rules that should be applied to the service, the unit and the period of costing (yearly or monthly).
0B PAR RESOURCES	<ul style="list-style-type: none">▶ Network resources are listed in this worksheet. Other parameters related to the resources and cost items are also defined here.
0C PAR KPIS	<ul style="list-style-type: none">▶ The Key Performance Indicators (KPIs) used to load data from the R Model are parametrized in this worksheet. The KPIs are defined differently for each access network.
0D PAR DRIVERS	<ul style="list-style-type: none">▶ The drivers are the variables used for the dimensioning of the network (e.g. Connections, Mbps). The list of drivers considered is included in this worksheet.▶ The rationale of the dimensioning drivers is to present traffic and demand (at service level) in a way that facilitates the dimensioning of network resources.
0E PAR GEOTYPES	<ul style="list-style-type: none">▶ The levels of disaggregation for the results of the services are parametrized in this worksheet. The disaggregation takes into account:<ul style="list-style-type: none">• Region• Geotype• Dwelling Unit• Regulation
0F PAR OTHER	<ul style="list-style-type: none">▶ Other parameters needed in the model are defined in this worksheet.

Exhibit 7.5: Parameters worksheets. [Source: Axon]

A.2.3. Step 1: Main inputs

The main inputs are those that need to be regularly updated to better represent the current characteristics of the operator under study. The worksheets defined in this block are described in the following table.



Sheet name	Description
1A INP DEMAND	▶ The demand (subscribers and traffic) that needs to be supported by the network is introduced in this worksheet. This demand is provided disaggregated based on the list of services defined in sheet "OA PAR SERVICES".
1B INP UNIT COSTS	▶ Unitary costs (differentiating CAPEX and OPEX) are defined in this worksheet for each resource introduced in sheet "OB PAR RESOURCES". In addition, the percentage of staff costs over OpEx is included along with the useful lives of the resources used to depreciate the different resources.
1C INP NW	▶ Network parameters needed for the dimensioning of the network (for instance, equipment's capacity, standard constants) are introduced in this worksheet.
1D INP NW EVO	▶ This worksheet presents several inputs related to the network that are expected to evolve over time.
1E INP ANCILLARY SERV	▶ The inputs required to calculate the costs of ancillary services are presented in this worksheet.
1F INP DEMAND DISTRIBUTION	▶ The distribution of lines per geotype and per technology is introduced in this worksheet. The sum for each technology and year must add up to 100%.

Exhibit 7.6: Main inputs worksheets. [Source: Axon]

A.2.4. Step 2: Advanced inputs

The second type of inputs, named as Advanced Inputs, mostly refers to inputs that have been extracted from the R model. As such, they are related to geographical information, technical parameters, etc, which is not expected to change significantly over time. The worksheets defined in this block are described in the table below:



Sheet name	Description
2A INP COVERAGE	<ul style="list-style-type: none">▶ The percentage of dwellings passed for each geotype and network is introduced in this worksheet.▶ The figures included in this worksheet are extracted from the R model.
2B INP NW INVENTORY	<ul style="list-style-type: none">▶ This worksheet contains the number of network element required to properly characterise each access network throughout the modelling period.▶ The figures included in this worksheet are extracted from the R model.
2C INP NW ELEMENT DIS	<ul style="list-style-type: none">▶ This worksheet contains the distribution of the network elements per configuration. This disaggregation represents the percentage of elements introduced in worksheet 2B that uses each type of configuration.▶ The figures included in this worksheet are extracted from the R model.
2D INP CORE & TX RINGS	<ul style="list-style-type: none">▶ The information related to the transmission links is introduced in this worksheet.▶ The information is introduced for each transmission network at ring/chain level. Specifically, it includes the number of nodes in the chain (without considering beginning and end nodes), the total road distances covered to connect all the nodes in the chain (including end and start nodes) and the percentage of total traffic handled by each ring/chain.▶ This information is used to calculate the elements and cost of the transmission network.▶ The figures included in this worksheet are extracted from the R model.
2E INP NW OTHER	<ul style="list-style-type: none">▶ This worksheet contains additional inputs from the R model, such as the length of the drops and the number of buildings. These inputs are used in the dimensioning process to properly dimension and split elements and costs into geotypes.▶ The figures included in this worksheet are extracted from the R model.

Exhibit 7.7: Advanced inputs worksheets. [Source: Axon]

A.2.5. Step 3: Mapping

The worksheets contained in this step are used to map the services with the drivers used for dimensioning and to define the routing factors used to allocate resources' costs to services. These worksheets are described in the table below:



Sheet name	Description
3A MAP DRIVERS	<ul style="list-style-type: none">▶ Relationships between services and dimensioning drivers for the different networks.▶ It must be noted that in order to obtain the drivers it is necessary to indicate which services are related to them. It should also be noted that a service is generally assigned to more than one driver as drivers represent traffic in a particular point of the network.
3B MAT DRIVERS	<ul style="list-style-type: none">▶ This worksheet calculates a relationship matrix between services and drivers based on the mappings defined in worksheet "3A MAP DRIVERS".
3C MAP ROUTING FACTORS	<ul style="list-style-type: none">▶ This worksheet defines the relationships between services and resources by means of the routing factors.▶ A Routing Factor is a measure of how many times a resource is used by a specific service during its provision. Hence, the more traffic a service generates, the higher the cost will be charged from the asset considered; and the higher utilisation of the asset, the higher cost taken.
3D MAT ROUTING FACTORS	<ul style="list-style-type: none">▶ This worksheet calculates a relationship matrix between services and resources based on the mappings defined in worksheet "3C MAP ROUTING FACTORS".
3E MAP WEIGHTS	<ul style="list-style-type: none">▶ This worksheet includes the weights to be considered when converting the demand introduced in worksheet "1A INP DEMAND" into the drivers defined in worksheet "0D PAR DRIVERS".

Exhibit 7.8: Mapping worksheets [Source: Axon]

A.2.6. Step 4: Drivers and demand factors

The worksheets contained in this step are used to calculate the drivers that will be used for the dimensioning of the network and the demand factors used for the allocation of the resources costs to services. These worksheets are described in the table below:



Sheet name	Description
4A CALC COPPER SHUTDOWN	<ul style="list-style-type: none">▶ This worksheet includes information related with the simulation of a copper shut down scenario. It is responsible for reallocating the unserved copper demand to fibre and coax access networks.
4B CALC DRIVERS	<ul style="list-style-type: none">▶ The total volume of the drivers over the whole country is calculated in this worksheet based on the matrix presented in the worksheet '3B MAT DRIVERS'.
4C CALC DEMAND FACTORS	<ul style="list-style-type: none">▶ Demand factors are used to transform the demand of the service into different types of units (e.g. from lines to Mbps). These factors are needed in order to be able to allocate the costs of different types of network elements to services.▶ This worksheet includes the relationships needed to transform the demand of the different services to the relevant types of demand.

Exhibit 7.9: Drivers and demand factors worksheets [Source: Axon]

A.2.7. Step 5: Dimensioning of the network

These worksheets are responsible for the dimensioning of the network and are described below:

Sheet name	Description
5A DIM TX & CORE	<ul style="list-style-type: none">▶ In this worksheet the transmission and core networks are dimensioned, calculating the necessary equipment that supports the relevant demand for each increment.▶ Calculations are presented for two different increments (shown when moving towards the right of the sheet).▶ The dimensioning of the network takes as starting point the drivers obtained in block 4 as well as other inputs extracted from blocks 1 and 2 (for instance, network parameters, coverage, etc.)
5B DIM GEO	<ul style="list-style-type: none">▶ In this worksheet the access network is dimensioned, calculating the necessary equipment that supports the relevant demand for each increment.▶ Calculations are presented for two different increments (shown when moving towards the right of the sheet).▶ The dimensioning of the network takes as starting point the drivers obtained in block 4 as well as other inputs extracted from block 1 and 2 (for instance, network parameters, coverage, etc.).
5C DIM GEO CONS	<ul style="list-style-type: none">▶ This worksheet consolidates the results from the dimensioning performed in the worksheets "5A DIM TX & CORE" and "5B DIM GEO" per geotype.▶ The results included in this worksheet appear as values, as they are controlled by the macro in charge of executing the model, which only copies them from the previous two worksheets and pastes them into this worksheet.

Exhibit 7.10: Network dimensioning worksheets [Source: Axon]



A.2.8. Step 6: Resource Costing

This step contains the worksheets related with the costing of resources. A description of these worksheets is provided in the following table:

Sheet name	Description
6A CALC RES CONS	▶ This worksheet consolidates the total number of resources for the access and core networks at a national level.
6B CALC RES UNIT COST	▶ This worksheet consolidates the unit costs of the resources and calculates the different unit cost (both CapEx and OpEx) of the resources throughout the modelling period, considering the unit costs and their trend.
6C CALC TILTED	▶ This worksheet calculates the total CapEx and OpEx under the tilted annuities methodology.
6D CALC ECO DEP	▶ This worksheet calculates the total CapEx and OpEx under the Economic Depreciation methodology
6E CALC INCR-COM COST	▶ This worksheet calculates the total Incremental and Common cost for each network element in the network. Additionally, the cost overheads of the network -such as G&A, IT or wholesale costs- are calculated in this worksheet
6F CALC ANC SERV COST	▶ This worksheet calculates the costs of the activities from the ancillary services considering the salary and salary trends included in sheet '1E INP ANCILLARY SERV'.

Exhibit 7.11: Resource costing worksheets [Source: Axon]

A.2.9. Step 7: Allocation of costs

This step contains the worksheets that are responsible for allocating the costs from the resources to the services. They are described below:



Sheet name	Description
7A GEO RES COSTS	▶ This worksheet calculates the total incremental, common and total cost of the different resources of the network for each of the geotypes defined in the model.
7B GEO SERV DEMAND	▶ This worksheet calculates the percentage of the demand of each service that is associated to each geotype. The results of this worksheet are used to allocate the costs of the resources at geotype level (worksheet '7A GEO RES COSTS') to services (worksheet '7C GEO SERV COSTS').
7C GEO SERV COSTS	▶ This worksheet presents the costs of each service for each geotype. The calculation is performed by taking into consideration the relevant demand for each service (considering the demand factors from worksheet '4C CALC DEMAND FACTORS'), as well as the costs of the services and the relevant routing factors.

Exhibit 7.12: Allocation of costs worksheets [Source: Axon]

A.2.10. Step 8: Results

The worksheets contained in this step provide detailed information about the results of the Excel model. These worksheets are described below:

Sheet name	Description
8A RESULTS SERV	▶ This worksheet consolidates the service cost per line and year.
8B RESULTS ANC SERV	▶ This worksheet calculates the cost of the ancillary services for each modelled year.

Exhibit 7.13: Results worksheets [Source: Axon]

A.2.11. Additional support sheets

In addition to the main blocks, the model includes two additional support worksheets with additional data. These worksheets are described below:



Sheet name	Description
SCENARIO RESULTS	▶ This worksheet consolidates the result of executing the "All geotypes" mode in the execution mode. Which calculates the results for each geotype independently
SCENARIO CHART	▶ This worksheet displays a chart with the data of sheet "SCENARIO RESULTS"
NETWORK RESOURCES KPIS	▶ This worksheet consolidates the results from the dimensioning performed in the worksheets "5A DIM TX & CORE" and "5B DIM GEO" for some groups of assets.
RESULTS PER RESOURCE	▶ This worksheet provides a disaggregation of the results of the access service per resource for the year selected by the user.
RESULTS EVALUATION	▶ This sheet provides several KPIS of the model to assess the adequacy of the results.

Exhibit 7.14: Additional worksheets [Source: Axon]

A.3. Understanding the control panel

The control panel represents the main interface between the user and the model, and it is presented in the "COVER" page. It is used to select the model's key inputs and methodological options, to configure the execution mode and to run the model. The following figure shows a snapshot of the control panel.

LRAIC Model for Fixed Networks

Control panel	
Execution mode	Full execution
Execution time	02:02
Degree of urbanisation	ALL <small>selected.degree.urbanisation</small>
Regulation	ALL <small>selected.regulation</small>
Dwelling	ALL <small>selected.dwelling</small>
Input scenarios	
Demand scenario	Base case <small>selected.demand.scenario</small>
Copper shutdown year	2,030 <small>selected.copper.shutdown</small>
% of fully depreciated assets for copper	50% <small>selection.fully.depreciated.percentage.copper</small>
% of fully depreciated assets for coax	- <small>selection.fully.depreciated.percentage.coax</small>
Annualisation methodology	Economic Depreciation <small>selection.annualisation.method</small>
WACC	4,50% <small>input.wacc</small>
Risk premium	- <small>input.risk.premium</small>
Model PTP networks as PON?	No <small>selection.PTP.as.PON</small>
Include cost of installation in recurrent fee?	Yes <small>selection.standard.installation</small>
Include cost of delayed installation in recurrent fee?	Yes <small>selection.delayed.installation</small>
Limit delayed drop installation to 30m in recurrent fee?	Yes <small>selection.30m.limitation</small>
Include digging in private parts for coaxial network?	Yes <small>selection.coax.private</small>

1

RUN

UPDATE KPIs

CONTENTS

MAP

GENERAL CHECK
OK

Exhibit 7.15: Snapshot of the control panel [Source: Axon]

The control panel is divided into the following blocks:

- ▶ Execution Panel
- ▶ Input scenario
- ▶ Results overview

These three blocks are described in the following paragraphs.

Important warning: the model needs to be run to see the impact on the results of any change made in the control panel.

A.3.1. Execution Panel

The Execution Panel displays information regarding the status and progress of the execution of the model. The following information is shown in this Panel:



▶ **Execution mode:** It displays the execution mode to be selected. The two options available are:

- Full execution: The model is completely executed. It takes roughly 4 minutes, depending on the computer.
- Costing only: The model is run from block 6 (included) onwards. This mode becomes handy to assess the impact of different costing scenarios when the number of resources is not expected to change. It takes roughly 2 minutes, depending on the computer.
- Single geotype: The model is run from block 6 (included) onwards. In this mode, the model performs the costing algorithms only for the model selected in the drop down menus below the execution mode option. It takes roughly 2 minutes, depending on the computer.
- All geotype scenarios: The model runs the "Single geotype" mode above, but for all the geotypes while saving the results in sheet "SCENARIO RESULTS". This mode takes, roughly 40 minutes to run, depending on the computer.

To obtain the relevant results for the whole network of the operator, the model should be run in the "Full execution mode", which includes the results for broadband traffic services¹⁴ for fibre and coax networks. Meanwhile, to obtain the most accurate results for the SMP area of the modelled operator for fibre and coax access services¹⁵, the model should be run in mode "Single geotype" and selecting the "regulated" geotypes in the drop menu in cell "C23".

Therefore, in order to calculate the complete unit cost for fibre and coax BSA services in the SMP area, the user shall add the following components: i) The access component run under the "Single geotype" mode in the regulated geotypes and ii) the broadband component run in the "Full execution" mode.

- ▶ **Execution Time:** Displays the duration of the current (or last) model execution.
- ▶ **Degree of urbanisation:** The user may select what degree of urbanisation to run when selecting the mode "Single geotype". The options are: URBAN, SUBURBAN, RURAL or ALL.

¹⁴ Including all "Broadband.Fibre" and "Broadband.Coax" services.

¹⁵ Including all "Access.Fibre" and "Access.Coaxial" services.



- ▶ **Regulation:** The user may select the area considering the regulation to run when selecting the mode "Single geotype". The options are: Regulated, Not-Regulated or ALL.
- ▶ **Dwelling:** The user may select what buildings should be studied when running the mode "Single geotype". The options are: Single-dwelling, Multi-dwelling or ALL.

The execution panel also includes a number of buttons:

- ▶ **RUN:** Press this button to launch the execution of the model.
- ▶ **UPDATE KPIS:** Press this button to load the KPIS from the R model. When this button is pressed Excel will prompt a window where the user is requested to select the file generated by the R model (*in case a wrong file is selected the excel will display an error message*).
- ▶ **CONTENTS:** Quick link towards the "CONTENTS" worksheet
- ▶ **MAP:** Quick link towards the "MAP" worksheet
- ▶ **GENERAL CHECK:** It shows an "OK" when no errors are registered in the last execution and a "Review worksheets" when issues have been found.

A.3.2. Input scenarios

The input scenarios panel includes up to nine options that may be adjusted to tailor the execution of the model to the user's objectives. These options are:

- ▶ **Demand scenario:** Allows the user to select different demand scenarios that may be defined in worksheet '1A INP DEMAND'.
- ▶ **Copper shutdown year:** Allows the user to select the year of the copper shutdown.
- ▶ **Percentage of Fully depreciated Assets for Copper.** The user may select what percentage of the GBV for copper networks of the modelled operator correspond to fully depreciated assets.
- ▶ **Percentage of Fully depreciated Assets for Coax.** The user may select what percentage of the GBV for Coax networks of the modelled operator correspond to fully depreciated assets.
- ▶ **Annualization methodology:** This parameter allows the user to select its desired annualization methodology (tilted annuities or economic depreciation).



- ▶ **WACC (Weighted Average Cost of Capital):** This parameter represents the average minimum remuneration required for the capital employed. The WACC is employed for the calculation of the cost of capital associated to fixed investments. A percentage must be introduced by the user.
- ▶ **Risk premium:** This parameter allows the consideration of an additional risk premium for fibre access network elements.
- ▶ **Model PTP networks as PON?:** This options allows the user to model all PTP networks in the model as PON.
- ▶ **Include standard cost of installation in the recurrent fee?:** This option enables the user to select if the standard cost of an installation is considered in the recurrent fee. In the case that "No" is selected, then the cost is included as a one-off fee.
- ▶ **Include extra cost of delayed installation in the recurrent fee?:** This option enables the user to select if the extra cost of a delayed installation is considered in the recurrent fee. In the case that "No" is selected, then the cost is included as a one-off fee.
- ▶ **Limit delayed drop installation to 30m in the recurrent fee? :** This option enables the user to select if the limit of the delayed drop installation to 30 meters should be applied or not in the recurrent fee result.
- ▶ **Include digging in private parts for coaxial network?:** This option enables the user to select if the digging in private parts should be included or not in the recurrent fee result.

A.3.3. Results overview

This panel allows the user to display the results of three different services, based on his selection of the following items:

- ▶ **Service:** Select a service from the list of services introduced in the model.

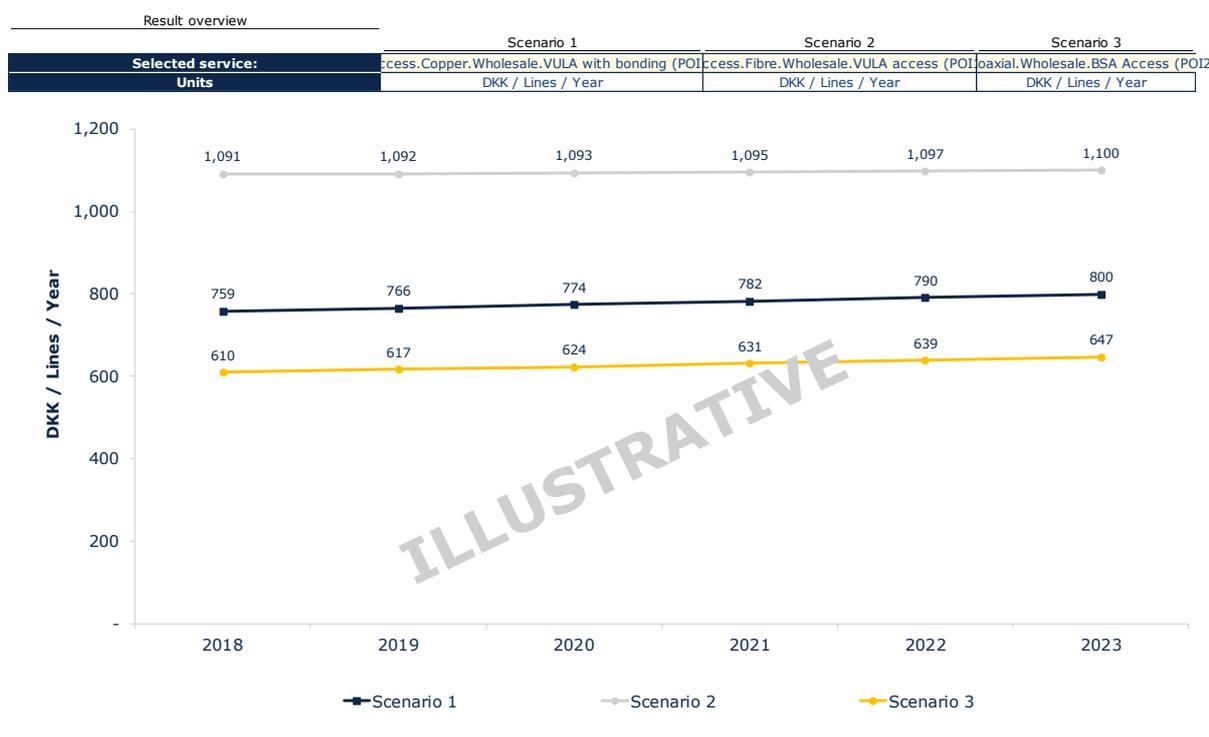


Exhibit 7.16: Result overview [Source: Axon]

A.4. Description of checks

This section describes the list of checks included in the worksheet "CHECKS" to guarantee the correct performance of the Excel model:

- ▶ **GENERAL CHECK:** This check indicates if the model is working properly or if it is necessary to review any of its worksheets and calculations.
- ▶ **Duplicity of resources unitary cost input:** This check indicates that there are duplicated resources in the worksheet "1B INP UNIT COSTS". The duplicated resource shall be removed.
- ▶ **Resources unitary cost input:** This check indicates that some resources are missing in the worksheet "1B INP UNIT COSTS". These missing resources should be included in this worksheet.
- ▶ **Invalid name of resource:** This check indicates that the name of a resource included in the worksheet "1B INP UNIT COSTS" is not correct and therefore, it should be adjusted.



- ▶ **Time Period:** This check indicates that the time period used in the model fits into the excel tables considered and thus allows a correct calculation.
- ▶ **Implementation of Economic Depreciation:** This check verifies that the sum of the depreciation and cost of capital charges obtained after calculating the economic depreciation is equal to the NPV of the resources depreciated.
- ▶ **Calculation of resource costs at geotype level:** This check indicates if there is any mistake in the allocations performed in the worksheet '7A GEO RES COSTS'.
- ▶ **Calculation of service costs at geotype level:** This check indicates if there is any mistake in the allocations performed in the worksheet '7C GEO SERV COSTS'.



Annex B. Description of the ancillary services

The described ancillary services in the table below provides description of the LRAIC-prices, which are calculated by the model. The table below is non-exhaustive for LRAIC prices, as there are additional services subject to LRAIC price regulation, which are based on the operator's historical costs instead.

Service Identifier	Service	Description (English)
5.5.2.1	Migration Services.From Raw/Shared Copper to BSA/VULA	<i>See name description</i>
5.5.2.2	Migration Services.From BSA/VULA (without PSTN) to Raw Copper	<i>See name description</i>
5.5.2.3	Migration Services.From BSA/VULA (without PSTN) to Shared Copper	<i>See name description</i>
5.5.2.4	Migration Services.From BSA (without PSTN) to BSA (with PSTN)	<i>See name description</i>
5.5.2.5	Migration Services.From BSA/VULA (without PSTN) to VULA	<i>See name description</i>
5.5.2.6	Migration Services.From ATM BSA to eBSA/VULA	<i>See name description</i>
5.5.2.7	Migration Services.From fibre BSA to Raw fibre	<i>See name description</i>
5.6.2.1	Installation.New installation (unassisted) – Raw Copper	<i>See name description. Unassisted = GDS</i>
5.6.2.2	Installation.New installation (unassisted) – Shared Copper	<i>See name description. Unassisted = GDS</i>
5.6.2.3	Installation.New installation (unassisted) – BSA	<i>See name description. Unassisted = GDS</i>
5.6.2.4	Installation.New installation (unassisted) – eBSA	<i>See name description. Unassisted = GDS</i>
5.6.2.5	Installation.New installation (unassisted) – VULA	<i>See name description. Unassisted = GDS</i>
5.6.2.6	Installation.New installation (unassisted) – Raw Fibre	<i>See name description. Unassisted = GDS</i>
5.6.2.7	Installation.New installation (engineer assisted) – Raw Copper	<i>See name description. Assisted = GIG</i>
5.6.2.8	Installation.New installation (engineer assisted) – Shared Copper	<i>See name description. Assisted = GIG</i>
5.6.2.9	Installation.New installation (engineer assisted) – BSA	<i>See name description. Assisted = GIG</i>
5.6.2.10	Installation.New installation (engineer assisted) – eBSA	<i>See name description. Assisted = GIG</i>
5.6.2.11	Installation.New installation (engineer assisted) – VULA	<i>See name description. Assisted = GIG</i>



Service Identifier	Service	Description (English)
5.6.2.12	Installation.New installation (engineer assisted) – Raw Fibre	<i>See name description.</i> Assisted = GIG
5.7.2.1	Additional Services.NTP	One time setup of KAP-stik/NTP. To be paid if installation of KAP-stik/NTP is needed when activating the connection
5.7.2.2	Additional Services.NTP incl. Drilling	To be paid when a technician, in continuation of a GIG installation, drills through the outer wall and threads a cable through to finish the setup by installing a NTP
5.7.2.3	Additional Services.Delayed installation	To be paid when an installation is performed after the deployment of the network
5.7.2.4	Additional Services.Physical rearrangement	To be paid upon rearrangement from one copper/fiber pair to another. Not to be paid if the raw copper connection is only used for PSTN or ISDN2
5.7.2.5	Additional Services.Change of trunk number	To be paid when a change of trunk number is requested
5.7.2.6	Additional Services.Visit by technician	"Time and material"-charge for technician time per hour within normal working hours.
5.7.2.7	Additional Services.Unproductive visit (Technician)	To be paid in case the technician cannot get access to the installation, e.g. due to the end user not being home
5.7.2.8	Additional Services.Cancellation-fee II	TDC is entitled to a cancellation fee, if the customer cancels the raw copper/fiber line after receipt of order confirmation from TDC's customer service and until 12.00 on the working day before delivery day. Cancellations after this deadline are to be regarded as regular termination. Also to be paid if the order after visitation cannot be followed through due to erroneous information from the customer. A new order would be necessary for installing raw fiber/copper and will be paid in accordance with normal orders.
5.7.2.9	Additional Services.Calculation of attenuation on the line	Calculation of attenuation/150 kHz. To be paid when calculation of attenuation is wanted
5.7.2.10	Additional Services.Unproductive fault handling	To be paid for unjustified or unsuccessful fault handling. In case TDC after attempt of fault handling can render probable that the reported fault is not due to TDC's circumstances.
5.7.2.11	Additional Services.Change of speed	One time fee for changing speeds on BSA products
5.7.2.12	Additional Services.Installation of Multichannel	Setup fee for installation of multichannel, per channel
5.7.2.13	Additional Services.Reactivated installation (unassisted)	Reactivation of installation. Same price as regular Installation fee w/o technician assistance (GDS) for Copper BSA and VULA
5.7.2.14	Additional Services.Reactivated installation (engineer assisted)	Reactivation of installation. Same price as regular Installation fee with technician assistance (GIG) for Copper BSA and VULA
5.7.2.15	Additional Services.Conversion from BSA online to BSA without co-production	Surcharge for converting to VULA/BSA without co-production



Service Identifier	Service	Description (English)
5.7.2.16	Additional Services.Re-establishing trunks	To be paid in case of re-establishing of trunks after TDC's bypass connection on CO, due to an error in operator's equipment
5.7.2.17	Additional Services.Migration of 30 or more connections in a project	To be delivered in a project flow
5.7.2.18	Additional Services.Fall back Express on GDS	To be paid in case a "visit by technician" is necessary in continuation of a GDS order with a view to establish the connection. The booking for "visit by technician" is to be placed in a special calendar for speedy processing
5.7.2.19	Additional Services.Fall back on GDS	To be paid in case a "visit by technician" is necessary in continuation of a GDS order with a view to establish the connection.
5.7.2.20	Additional Services.Fall back in connection to debugging	To be paid if a technician, despite unjustified or unsuccessful fault handling, fixes the problem, e.g. by installing a KAP-stik/NTP
5.7.2.21	Additional Services.Manual order	To be paid if the operator uses the order type through the manual ordering interface, although the order type also exists in Columbine.
5.7.2.22	Additional Services.Additional fee for cable distributor	To be paid if the connection is established from a position, where DSLAMs are located in street cabinets
5.7.2.23	Additional Services.Digging/blowing per meter, above 30 meters, per meter	Per meter price for above 30 meters, when digging/blowing of final dropline from fiber point to NTP at end user. To be paid as a one-off total price.
5.7.2.24	Additional Services.Move	To be paid upon relocation of fixed telephone
5.7.2.25	Additional Services.Conversion GDS between PSTN and ISDN	To be paid upon conversion (w/o technician assistance) between PTSN and ISDN
5.7.2.26	Additional Services.Cancellation	TDC is entitled to a cancellation fee, if the customer cancels the BSA/VULA line after receipt of order confirmation from TDC's customer service and until 12.00 on the working day before deliverance day. Cancellations after this deadline are to be regarded as regular terminations. Also to be paid of the order after visitation cannot be followed through due to erroneous information from the customer. A new order would be necessary for installing BSA/VULA and will be paid in ordance with normal orders
5.7.2.27	Additional Services.Mac addresses 32/64	<i>See name description</i>
5.8.2.1	Exchange Traffic.Setup of pre-selection	Fixed fee for setup of pre-selected operator in relation to handing over a new/existing resale customer. (Deregulated in accordance with prefix)
5.8.2.2	Exchange Traffic.Implementation of prefix for pre-selection	<i>No description available</i> (Deregulated in accordance with prefix)
5.8.2.3	Exchange Traffic.Pre fix for switched interconnection, basic fee, implementation	<i>No description available</i> (Deregulated in accordance with prefix)
5.8.2.4	Exchange Traffic.Pre fix for switched interconnection, per central, implementation	<i>No description available</i> (Deregulated in accordance with prefix)



Service Identifier	Service	Description (English)
5.8.2.5	Exchange Traffic.Pre fix with same routing as established pre fix from same operator for switched interconnection, per central, implementation	<i>No description available</i> (Deregulated in accordance with prefix)
5.8.2.6	Exchange Traffic.Pre fix for switched interconnection, per central, change	<i>No description available</i> (Deregulated in accordance with prefix)
5.8.2.7	Exchange Traffic.Pre fix with same routing as established pre fix from same operator for switched interconnection, per central, change	<i>No description available</i> (Deregulated in accordance with prefix)
5.8.2.8	Exchange Traffic.Pre fix for local interconnection, per central, change	<i>No description available</i> (Deregulated in accordance with prefix)
5.8.2.9	Exchange Traffic.Local POI - Installation	<i>No description available.</i> <i>No longer regulated</i>
5.8.2.10	Exchange Traffic.Local POI - Annual cost	<i>No description available</i>
5.8.2.11	Exchange Traffic.Interconnection capacity (2 Mbit/s port/30-group) - Installation	<i>No description available</i>
5.8.2.12	Exchange Traffic.Interconnection capacity (2 Mbit/s port/30-group) - Annual cost	<i>No description available</i>
5.9.2.1	Backhaul.New Installation, Street Cabinet Backhaul - dark fibre	Back haul fiber, single fiber
5.9.2.2	Backhaul.Interconnection of fibre pairs in optic distributor between points termination	Interconnection of fibre connection in optic distributor between termination points
5.9.2.3	Backhaul.Interconnection of fibre pairs in socket (splicing) between points of termination	Interconnection of fibre pairs in socket (splicing) between termination points
5.9.2.4	Backhaul.Cancellation fee pr. fibre pair or tube	<i>No description available</i>
5.9.2.5	Backhaul.Debugging per hour	Debugging per hour or part thereof in connection with backhaul fiber
5.9.2.6	Backhaul.Measurement report for fibre pairs	Measurement report for fiber connection (backhaul fiber)
5.10.2.1	Backhaul and transport Bitstream.Inspection between 07 AM and 6 PM	<i>No description available</i>
5.10.2.2	Backhaul and transport Bitstream.Additional fee for inspection between 6 PM and 7 AM	<i>No description available</i>
5.10.2.3	Backhaul and transport Bitstream.Cancellation fee, order received	Cancellation fee, order received Furthermore: - After receipt of order confirmation, 10% of setup fee to be paid. - After passing 50% of confirmation time in number of days from receipt of order confirmation, 50% of the setup fee to be paid - After passing 75% of confirmation time in number of days from receipt of order confirmation, 75% of the setup fee to be paid - later than days before confirmed delivery and prior to usage, to be seen as regular termination. (Deregulated in accordance with Ethernet transport)



Service Identifier	Service	Description (English)
5.10.2.4	Backhaul and transport Bitstream.Postponement fee, order received	<i>No description available.</i> (Deregulated in accordance with Ethernet transport)
5.10.2.5	Backhaul and transport Bitstream.Postponement fee, later than one week before confirmed delivery	<i>No description available.</i> (Deregulated in accordance with Ethernet transport)
5.10.2.6	Backhaul and transport Bitstream.Postponement fee, at point of delivery	At the time of delivery, in addition payment of quarterly rent will also be charged. (Deregulated in accordance with Ethernet transport)
5.10.2.7	Backhaul and transport Bitstream.Unwarranted claim for debugging, transmission	Payment for unproductive or unwarranted error handling, unless otherwise stated in bilateral agreement. (Deregulated in accordance with Ethernet transport)
5.11.2.1	Colocation.Shelf incl. part of the tripod – Installation	One rack section BxDxH = 600x300x400/600x600x400.
5.11.2.2	Colocation.Shelf incl. part of the tripod – Annual cost	One rack section BxDxH = 600x300x400/600x600x400.
5.11.2.3	Colocation.Rack space (1.5 m 2) - Installation	<i>See name description</i>
5.11.2.4	Colocation.Rack space (1.5 m 2) – Annual cost	<i>See name description</i>
5.11.2.5	Colocation.Installation of VAC or VDC power equipment	Installation fee for the power equipments of 5.11.2.6 - 5.11.2.12
5.11.2.6	Colocation.Annual Cost (1 * 48 VCD 16 A 100W)	<i>See name description.</i> Includes usage
5.11.2.7	Colocation.Annual Cost (1 * 48 VCD 16 A 200W)	<i>See name description.</i> Includes usage
5.11.2.8	Colocation.Annual Cost (1 * 48 VCD 16 A 500W)	<i>See name description.</i> Includes usage
5.11.2.9	Colocation.Annual Cost (1 * 48 VDC 30 A)	<i>See name description.</i> Includes usage
5.11.2.10	Colocation.Annual Cost (1 * 48 VDC 60 A)	<i>See name description.</i> Includes usage
5.11.2.11	Colocation.Annual Cost (1 * 230 VAC 10 A)	<i>See name description.</i> Includes usage
5.11.2.12	Colocation.Annual Cost (1 * 230 VAC 10 A service socket)	<i>See name description.</i> Includes usage
5.11.2.13	Colocation.Shift to another power-product	One-off fee for migration to another power outlet
5.11.2.14	Colocation.Supervised access	Hourly charge rate for supervised access without prior notification, i.e. immediate assistance, during day-time.
5.11.2.15	Colocation.Inquiry	To be paid upon ordering investigations for the possibility of co-locating technician houses in the central office. The payment will be refunded, if a contract is signed based on offer
5.11.2.16	Colocation.Co-location in technical house	Submission of offer on co-locating technician houses in the central office
5.11.2.17	Colocation.Trunk cables PDS 2*cat.5 Installation	<i>No description available</i> (No longer supplied by TDC)
5.11.2.18	Colocation.Trunk cables PDS 2*cat.5 per 10 m	<i>No description available</i> (No longer supplied by TDC)



Service Identifier	Service	Description (English)
5.11.2.19	Colocation.Trunk cables PDS 10*cat.5 Installation	<i>No description available</i> (No longer supplied by TDC)
5.11.2.20	Colocation.Trunk cables PDS 10*cat.5 per 10 m	<i>No description available</i> (No longer supplied by TDC)
5.11.2.21	Colocation.Trunk cables 12 fibre pair (sm) Installation	Optical trunk terminated in TDC's distributor, 24 fibre (12 pairs) - installation
5.11.2.22	Colocation.Trunk cables 12 fibre pair (sm) per 10 m	Optical trunk terminated in TDC's distributor, 24 fibre (12 pairs) - per 10 m
5.11.2.23	Colocation.Internal cabling mm PDS 2*cat.5 Installation	<i>No description available</i> (No longer supplied by TDC)
5.11.2.24	Colocation.Internal cabling mm PDS 2*cat.5 per 10 m	<i>No description available</i> (No longer supplied by TDC)
5.11.2.25	Colocation.Internal cabling mm PDS 10*cat.5 Installation	<i>No description available</i> (No longer supplied by TDC)
5.11.2.26	Colocation.Internal cabling mm PDS 10*cat.5 per 10 m	<i>No description available</i> (No longer supplied by TDC)
5.11.2.27	Colocation.Internal cabling mm 12 fibre pair (sm) Installation	Optical cable without termination, 24 fibre (12 pairs) - installation
5.11.2.28	Colocation.Internal cabling mm 12 fibre pair (sm) per 10 m	Optical cable without termination, 24 fibre (12 pairs) - per 10 m
5.11.2.29	Colocation.Internal cabling mm 8 Coax pair Installation	<i>See name description</i>
5.11.2.30	Colocation.Internal cabling mm 8 Coax pair per 10 m	<i>See name description</i>
5.11.2.31	Colocation.Internal cabling mm 24 coax pair Installation	<i>See name description</i>
5.11.2.32	Colocation.Internal cabling mm 24 coax pair per 10 m	<i>See name description</i>
5.11.2.33	Colocation.Internal cabling mm 100 copper pair Installation	100 copper pair cable trunk terminated in TDC's intersection, installation
5.11.2.34	Colocation.Internal cabling mm 100 copper pair per 10 m	<i>See name description</i>
5.11.2.35	Colocation.Internal cabling mm 3*100 copper pair Installation	300 copper pair cable trunk terminated in TDC's intersection, installation
5.11.2.36	Colocation.Internal cabling mm 3*100 copper pair per 10 m	<i>See name description</i>
5.11.2.37	Colocation.Internal cabling in-span fibre Installation	In-span optical fiber cable, 48 fibre (24 pair) - installation
5.11.2.38	Colocation.Internal cabling in-span fibre per 10 m	<i>See name description</i>
5.11.2.39	Colocation.Technical house led/cover - delivery of led/cover	One cover per section
5.11.2.40	Colocation.Technical closet in technical house - Installation	<i>No description available</i>
5.11.2.41	Colocation.Technical closet in technical house - Monitoring and battery check	<i>No description available</i>



Service Identifier	Service	Description (English)
5.11.2.42	Colocation.Technical closet in technical house - 48 VDC 100W. Installation of point outlet with cable and fuse	One-off fee
5.11.2.43	Colocation.Technical closet in technical house - 48 VDC 100W. Each year inclu. Utilities	One 48 VDC outlet incl. usage (100 W)
5.11.2.44	Colocation.Delivery and installation of DSL closet without co-production	<i>No description available</i> (Deregulated in accordance with sub-loops on copper)
5.11.2.45	Colocation.Delivery and installation of DSL closet with co-production	<i>No description available</i> (Deregulated in accordance with sub-loops on copper)
5.11.2.46	Colocation.230 VAC, 4A supply incl. Fuse and monitoring device	<i>No description available</i> (Deregulated in accordance with sub-loops on copper)
5.11.2.47	Colocation.1x100 pair cables and fibre trunk incl. Digging and termination of 1x100 copper pairs and 4 fibres	<i>No description available</i> (Deregulated in accordance with sub-loops on copper)
5.11.2.48	Colocation.1x100 pair cable with termination at TDC	<i>No description available</i> (Deregulated in accordance with sub-loops on copper)
5.11.2.49	Colocation.Fibre trunk with termination of 4 fibres i distributor at TDC	Delivery of only fiber trunk with termination of 4 fibres in TDC's distributor. Both co-location and co-production. Maximum 10 meter, lengths above this requires tender offer
5.11.2.50	Colocation.Fibre trunk with termination of 4 fibres in socket (splicing) at TDC	Delivery of only fiber trunk with termination of 4 fibres in TDC's socket (splicing). Both co-location and co-production. Maximum 10 meter, lengths above this requires tender offer
5.11.2.51	Colocation.Hourly rate for re-registration of co-location, e.g. from quarterly to monthly payment of rent	<i>No description available</i>

Exhibit 7.17: Description of the ancillary services [Source: Axon]



Annex C. List of acronyms

BEREC	Body of European Regulators for Electronic Communications
BSA	Bitstream Access
BU	Bottom-Up
BU-LRAIC	Bottom-up Long-run Average Incremental Costs
CAPEX	Capital expenditure
CMC	Coaxial Media Converter
CO	Central Office
CSV	Comma-separated values
DBA	Danish Business Authority
DKK	Danish Krone
DP	Distribution Point
DWDM	Dense wavelength division multiplexing
EC	European Commission
EPMU	Equal Proportionate Mark-Up
FDP	Final Distribution Point
FTTC	Fibre to The Cabinet
G&A	General and Administrative
GPON	Gigabyte Passive Optical Networks
IP	Internet Protocol
IT	Information and Technology
Kbps	Kilobit per second
LRAIC	Long-run average incremental cost
Mbps	Megabit per second
MDF	Main Distribution Frame
MRP	Model Reference Paper
MSAN	Multi-Service Access Nodes
ODF	Optical Distribution Frame
OECD	Organisation for Economic Co-operation and Development
OLT	Optical Line Terminal
OPEX	Operational expenditure
PDP	Primary Distribution Point
PON	Passive Optical Network
PTP	Point to Point



SC	Street Cabinet
SDP	Secondary Distribution Point
SMP	Significant Market Power
VoD	Video on Demand
VoIP	Voice over IP
WACC	Weighted Average Cost of Capital

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