# AXON

**Excellence in Business**

# Cost Model for Fixed Networks

## Descriptive Manual

**Axon Partners Group**

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# Contents

# 1.    Introduction

This report describes the modelling approach, model structure and calculation process followed in the development of the Bottom-up Long Run Incremental Cost (BU-LRIC) Model for fixed networks ('the Model') commissioned by HAKOM to Axon Partners Group Consulting (hereinafter, Axon Consulting).

The model has the following main characteristics:

▶ It calculates the network cost of the services under the LRIC+ cost standard which includes common costs.

▶ It is based on engineering modules that allow the consideration of a multiple year time frame.

This section presents the main methodological aspects that have been considered in the development of the Model and provides an overview of the structure of this Document.

## 1.1. Methodological choices

The key structural and methodological choices were discussed with HAKOM and consulted with stakeholders, and they define the framework for the implementation of the Model.

The following table contains a summary of the methodological framework that has been set for the development of the Model.

| Methodological Issue | Approach Adopted |
|---|---|
| Cost Standard | ▶ LRIC+ (Long Run Incremental Costs Plus Common Costs) |
| Asset valuation | ▶ Current Cost Accounting (CCA) |
| Costs considered | ▶ Network CapEx (Depreciation and Cost of Capital), Network OpEx, G&A costs and Wholesale specific costs |
| Annualization method | ▶ Tilted annuity and Economic Depreciation |
| Allocation of common network costs | ▶ Network related common costs based on an Effective Capacity approach<br>▶ G&A and Wholesale specific common costs based on an EPMU[1] approach |
| Network Topology | ▶ Scorched Node, using the existing locations of operators' network nodes |
| Time horizon | ▶ From 2017 until 2027 |
| Type of operator | ▶ Hypothetical efficient operator rolling out modern efficient networks |
| Reference operator | ▶ Hrvatski Telekom (HT) |
| Geographical modelling | ▶ External model that characterizes the routes followed by the cables to provide coverage to the buildings database extracted from the DGU[2] |
| Technology and network | ▶ Access: Copper and Fibre<br>▶ Transmission: Microwave Links and Fibre Links (DWDM and IP/MPLS)<br>▶ Core: NGN Core Network |

**Exhibit 1.1: Summary of the methodological framework. [Source: Axon Consulting]**

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[1] EPMU = Equi-Proportional Mark-Up

[2] Državna geodetska uprava (State Geodetic Administration) https://dgu.gov.hr/

## 1.2. Structure of the document

The remaining sections of this document describe the modelling approach, the model structure and the calculation process followed.

The document is structured as follows:

▶ **General Architecture of the Model**, introduces the general structure of the Model, from the Demand module to the Network Dimensioning and Costing modules.

▶ **Model inputs**, introduces the main inputs needed for the Model.

▶ **Dimensioning drivers**, examines the conversion of traffic (at service level) to network parameters (for Mbps) facilitating the dimensioning of network resources.

▶ **Geographical Analysis**, presents the treatment performed to the geographical characteristics of the country in order to adapt it to the needs of the BULRIC Model.

▶ **Dimensioning Module**, illustrates the criteria followed in order to design the network and calculate the number of resources required to serve the coverage and capacity constraints.

▶ **CapEx & OpEx Costs Module**, presents the calculation of annual OpEx and CapEx over the years.

▶ **Depreciation Module**, presents the calculation of the depreciation methods to distribute CAPEX over the years (annualisation).

▶ **Cost allocation to services**, includes further explanations about the calculation of costs under the LRIC+ standard and it also presents the methodology used for the allocation of resources' costs to the services.

Finally, a user manual has been produced, which is provided as a separate document.

# 2. General Architecture of the Model

This chapter of the document introduces the general structure of the Model. The following figure shows the function blocks and their interrelationship in the model.
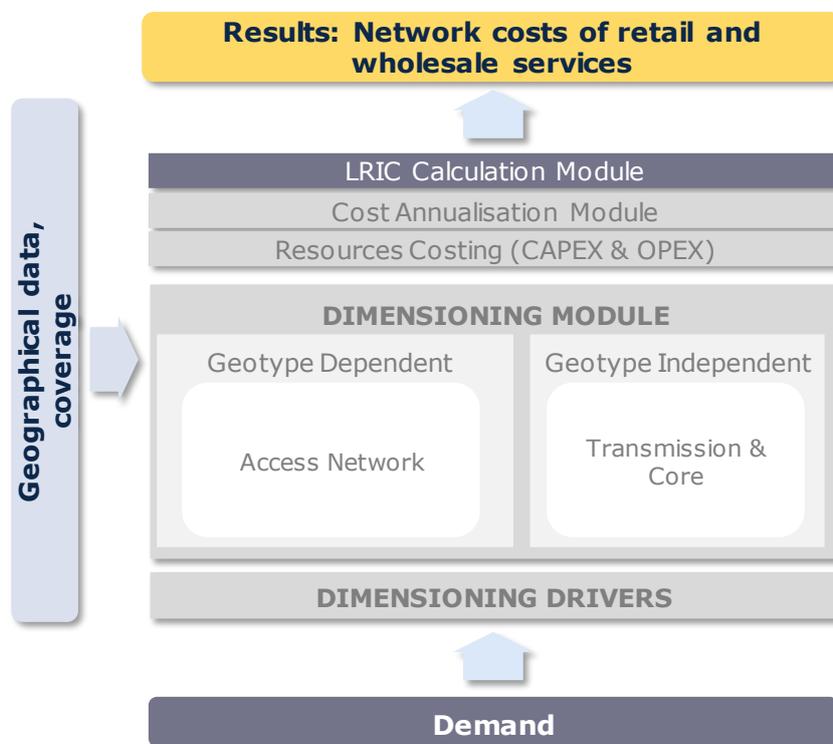


**Exhibit 2.1: Structure of the model [Source: Axon Consulting]**

Several function blocks can be identified but, as a first classification, the following parts are described below:

▶ **Dimensioning drivers:** Converting demand and traffic into dimensioning drivers, later assisting in dimensioning network resources.

▶ **Dimensioning module:** Computing the number of resources and building the network that can supply the main services provided by the reference operator.

The estimated demand for all modelled services is used by the Dimensioning Module.

Additionally, geographical data is introduced in the dimensioning module to take into consideration the relevant geographical aspects of the country.

The model recognises that the different parts of the reference operator's network can be geotype-dependent or independent. For example, the dimensioning process corresponding to the access network and the access infrastructure is distinctive and independent for each geo-type.

- ▶ **Cost Calculation (CapEx and OpEx):** Calculating cost of resources obtained after network dimensioning, both in terms of CapEx and OpEx.

- ▶ **Annualisation module:** Allocating CapEx resources costs over time following the methodology defined. That is, employing a tilted annuities method or economic depreciation method.

- ▶ **LRIC costs calculation module**: Obtaining pure incremental costs related to the different increments (each increment is defined as a group of services) and common costs.

The following sections further develop each block of the model.

# 3. Model inputs

By definition, the main input of a BULRIC model is the demand that should be satisfied by the network to be dimensioned. However, additional data is required. The following list describes the main inputs that are needed for the BULRIC Model:

▶ **Coverage**: the coverage achieved (in terms of households passed) has a considerable impact in the results of the Model. Therefore, historical and forecast coverage by geotype needs to be introduced into the Model.

▶ **Geographical information**: the dimensioning of the network requires to take into consideration specific information about the different areas of the country. This information is aggregated in geotypes. Additionally, the characterisation of the core network is needed (e.g. core locations, links). Geographical information is produced by applying the methodology described in section 5.

▶ **Traffic statistics**: for the dimensioning of the network it is necessary to define certain statistics of the network (e.g. TV channel throughput).

▶ **Network dimensioning parameters and equipment capacity**: dimensioning algorithms need information about the characteristics of the network equipment in terms of capacity.

# 4.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.

This section presents the following aspects about the dimensioning drivers:

▶ Dimensioning drivers concept

▶ Mapping services to drivers

▶ Conversion Factors from Services to Drivers

## 4.1. Dimensioning drivers concept

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

Dimensioning drivers represent, among others, the following requirements:

▶ Number of connections for the dimensioning of the access network

▶ Mbps for transmission through the core network (including for instance broadband and TV services).

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

| VARIABLE |
|---|
| DRIV.FIBRE.Connections.Total Active connection |
| DRIV.COPPER.Connections.Total Active connection |
| DRIV.FIBRE.Final Installation.Final Installation |
| DRIV.COPPER.Final Installation.Final Installation |
| DRIV.METRO TRAFFIC.Traffic.Data traffic |
| DRIV.REGIONAL TRAFFIC.Traffic.Data traffic |
| DRIV.MAIN TRAFFIC.Traffic.Data traffic |
| DRIV.METRO TRAFFIC.Traffic.High-Quality Services |
| DRIV.REGIONAL TRAFFIC.Traffic.High-Quality Services |
| DRIV.MAIN TRAFFIC.Traffic.High-Quality Services |

| VARIABLE |
|---|
| DRIV.IPAC TRAFFIC.Traffic.Data traffic |
| DRIV.SPOKE TRAFFIC.Traffic.Data traffic |
| DRIV.HUB TRAFFIC.Traffic.Data traffic |
| DRIV.IPAC TRAFFIC.Traffic.High-Quality Services |
| DRIV.SPOKE TRAFFIC.Traffic.High-Quality Services |
| DRIV.HUB TRAFFIC.Traffic.High-Quality Services |
| DRIV.CORE CONNECTIONS.Connections.Total lines |
| DRIV.CORE CONNECTIONS.Connections.Total Internet lines |
| DRIV.IPTV.Traffic.Traffic |
| DRIV.VOD.Traffic.Traffic |
| DRIV.TERMINATING SEGMENT.High-Quality Services.High-Quality Services |

**Exhibit 4.1: List of Drivers used in the model (Sheet '0C PAR DRIVERS'). [Source: Axon Consulting]**

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.

## 4.2. Mapping services to drivers

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

For example, broadband services should be contained in both the drivers used to dimension the transmission network (i.e. the links) as well as the core equipment.

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

| List of relationships | |
|---|---|
| **SERVICE (Variable Name)** | **DRIVER (Variable Name)** |
| Access.FTTH.Retail.Access | DRIV.FIBRE.Connections.Total Active |
| Access.FTTB.Retail.Access | DRIV.FIBRE.Connections.Total Active connection |
| Access.FTTDP.Retail.Access | DRIV.FIBRE.Connections.Total Active connection |
| Access.FTTH - Unbundled at DP level (PTP) .Wholesale - Local Access Lines - Market | DRIV.FIBRE.Connections.Total Active connection |
| Access.FTTH - Unbundled at ODF level | DRIV.FIBRE.Connections.Total Active |
| Access.FTTH.Wholesale - Central Access Lines | DRIV.FIBRE.Connections.Total Active |
| Access.FTTB.Wholesale - Central Access Lines | DRIV.FIBRE.Connections.Total Active |
| Access.FTTDP.Wholesale - Central Access Lines - Market 3B.Access | DRIV.FIBRE.Connections.Total Active connection |

**Exhibit 4.2: Example from the Mapping of Services into Drivers (Sheet '3A MAP SERV TO DRIV')**
**[Source: Axon Consulting]**

## 4.3. Conversion Factors 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 factor has been defined representing the number of driver units generated by each demand service unit. In general, conversion factors calculation consists of two subfactors, in compliance with the following structure:
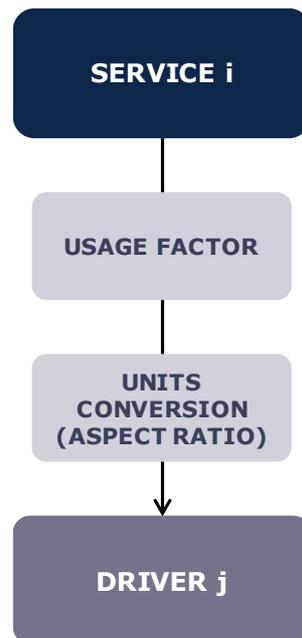
**Exhibit 4.3: Conversion Process from Services to Drivers [Source: Axon Consulting]**

The conversion factor thus includes the following items:

1. Usage Factor (UF)
2. Units Conversion Factors (UCF)

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

$$FC = UF * UCF$$

**Usage factor** represents the number of times a service makes use of a specific resource. These factors are defined in the column D of worksheet `3A MAP SERV TO DRIV´.

**Unit conversion** represents the need to adapt services' units (e.g. channels) to those used by the driver (e.g. Mbps). These factors are defined in the column I of worksheet `3A MAP SERV TO DRIV´.

# 5. Geographical Analysis

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.

The main purpose of this analysis is the definition of the network characteristics, mainly the location of network nodes (in case the position is not known) and the definition of the routes to connect them. This characterization is later aggregated into areas that share similar characteristics, grouped by means of geotypes. This information is finally used for the dimensioning of the access network, as described in further detail in section 6.

The geographical analysis is performed in an external model developed with R, since this is a powerful tool that permits to work with high volumes of data such those needed in this case. The main results obtained from the geographical analysis are loaded into the main excel model as geographical inputs (in worksheet "2B INP GEO DATA").

The steps followed in order to carry out the geographical analysis have been split according to their nature between 3 main blocks:

▶ Input Assessment

▶ Geographical calculations

▶ Outputs treatment
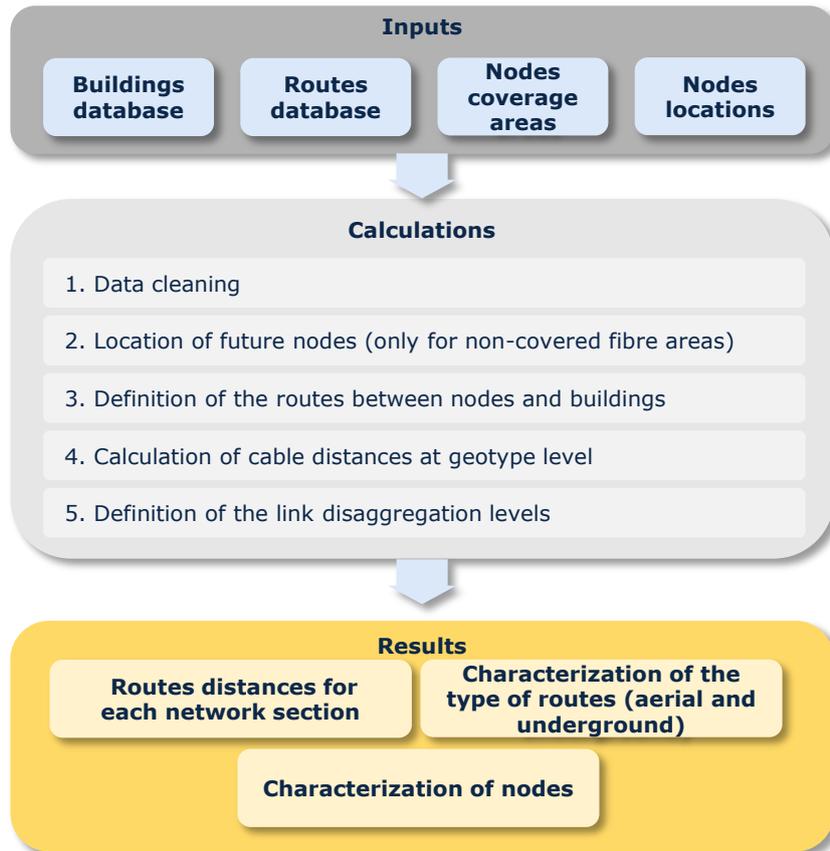
**Exhibit 5.1: Architecture of the external model developed in R for the geographical analysis**

The detail of the activities carried out in each step is explained below in further detail.

## 5.1. Input Assessment

For the development of the geographical analysis, several databases have been used. The main files used for the geographical analysis are:

| Data | Description | Source |
|---|---|---|
| **Buildings database** | SHP file collecting all the buildings and their coordinates in Croatia | DGU |
| **Households database** | Excel files presenting the number of households in Croatia (census 2011), and the new built households in the last years (since 2011) | DRŽAVNI ZAVOD ZA STATISTIKU REPUBLIKE HRVATSKE CROATIAN BUREAU OF STATISTICS |
| **Routes database** | SHP file containing all the information related to HT's network[3] | Hrvatski Telekom |
| **Coverage database** | File containing the coverage area of each main node location. | Hrvatski Telekom |
| **Node location** | Location of the main nodes of the access and transmission network | Hrvatski Telekom |

**Exhibit 5.2: Databases and sources used in the geographical analysis [Source: Axon Consulting]**

The databases available represent the main inputs of the geographical analysis. The following sections further develop about each of these inputs.

### 5.1.1 Buildings database

The address database contains a list of all the Croatian buildings, giving mainly the detail of:

▶ Address (including Street, Street number, Settlement and County)

▶ Coordinates (in HTRS96)

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[3] The information on HT's routes has also been contrasted with the information about streets/roads collected from the State Geodetic Administration (Državna geodetska uprava - DGU), to ensure that HT's routes did not present inefficiencies.

This information is essential to extract relevant information about the buildings in Croatia, which is used to evaluate the footprint of the modelled operator.



**Exhibit 5.3: Extract of the buildings available in the buildings database [Source: Source: Axon Consulting based on DGU's data]**

## 5.1.2 Households database

The households' database comprises two different sets of data from the Croatian Bureau of Statistics (DZS):

▶ Number of households per county from the census carried out in 2011.

▶ New households built per county per year from 2011 up to date.

Hence, combining these sets of information, the actual number of households per county in Croatia is calculated.

It is important to note that, during the data gathering process, HT submitted a figure for the total number of households in Croatia which differed from the total number of households available at the DZS. In light of this, it was decided to finally use the information from the DZS as preferential source for the total number of households in the model, since this corresponds to an official source and additionally, it is the source that was defined in the Methodological Document.

### 5.1.3 Routes database

The routes database contains a list of all the routes in HT's network. The routes are disaggregated in sections, which represent the routes between two intersections. In addition, three different types of routes are used for the network deployment:

▶ Aerial

▶ Directly buried into the ground (without ducts)

▶ Buried with ducts

Where each section is classified according to one of these groups.



**Exhibit 5.4: Extract of the routes available in the routes database [Source: Axon Consulting based on HT's data]**

It is worth outlining that the distance between two intersections is considered as the sum of the distances of all subsections between them.

### 5.1.4 Coverage database

The coverage database consists in GIS files reported by HT including the areas covered by each of the Main Distribution Frame (MDFs) in the case of copper network, and each Optical Distribution Frame (ODFs) currently installed, in the case of fibre networks.

**Exhibit 5.5: Example of MDFs and its coverage areas in Croatia [Source: Axon Consulting based on HT's data]**

## 5.1.5  Location of nodes

As presented in section 1.1 of this document, the model follows a scorched-node approach based on the actual network of the modelled operator. Thus, one of the most important datasets for the definition of the geographical analysis is the location of the operator's network nodes.

The information provided during the data request process by HT contained a database with the network nodes locations including the positions of the Distribution Points for both copper and fibre networks, the position of the Main Distribution Frames (MDFs) of copper networks as well as the position of the already existing Optical Distribution Frames (ODFs) of fibre networks (generally co-located with copper locations).

In the case of fibre nodes, only the nodes currently active or planned for 2020 have been reported by HT, as the position for the rest of future nodes is still unknown. For the future deployment of fibre, the operator has provided indications about the design-rules followed during the fibre roll-out, which has been employed to estimate the number of nodes in non-covered areas needed in future fibre deployments.

First of all, the number of ODFs is estimated based on these rules for the areas where no fibre coverage currently exists, and their locations are simulated by means of optimization algorithms (k-means), to determine the optimal locations of the new nodes. The operator has also explained that it plans to reuse the existing MDFs locations for the accommodation

of the new ODFs. Thus, the last step for determining the ODFs' locations has consisted in translating the estimated ODF optimal position towards the closest MDF position.

After the determination of the ODFs, since typically, the number of ODFs is lower than the number of MDFs, the coverage area of the ODFs is established as the union of the coverage areas of the closest MDFs. Once the coverage is settled, the number of households and the area covered are known, and thus, it is possible to determine the number and optimal location of the Distribution Nodes (DNs) for non-currently covered fibre areas, making also use of optimization algorithms (k-means).

## 5.2. Geographical calculations

The objective of the second block of the geographical analysis is the determination of routes distances for the different network sections. This information is relevant in order to properly dimension the access network, since the information in terms of distances needed between network elements is a fundamental input of the model.

As presented above, the locations of the network nodes are primarily based on data from the modelled operator.

Once the location of the different network elements is established (MDFs and DPs in case of copper and ODFs, DNs and DPs in case of fibre), there are a number of tasks to complete in order to fully characterize the access network:

***Association of the buildings to its corresponding node***

One of the key areas to characterize the access network is to determine the area covered by each DP/DN.

To do so, the following steps have been followed:

1. Identification of buildings and nodes inside the same coverage area. This is based on the boundaries provided by the operator.

2. Taking into account the geographical coordinates of the buildings and the nodes (DP/DN), each building has been associated to the closest node through the selection of the shortest paths. As shown in the exhibit below, this allows to identify the buildings covered by each node:

**Exhibit 5.6: Example of links between buildings and distribution points for copper network [Source: Axon Consulting]**

The output of this process has been mainly used in the definition of the routes between the buildings and the nodes, facilitating the determination of the optimal routes.

### Definition of routes between nodes

Once the buildings are associated to a specific node, the next step consists in the calculation of the routes connecting each DP/DN to its corresponding MDF/ODF. As the routes of the network are mainly used to determine the total distance needed for cables, trenches, etc., the results extracted from this analysis are very relevant for the network dimensioning.

Steps to calculate the routes between the network nodes are similar to those described in the previous section to connect the buildings to their corresponding node. The process to calculate the routes is based on the calculation of the shortest path between the nodes, considering the different possible paths through the operator's network.

First of all, each DP/DN is assigned to a parent node MDF/ODF according to the shapes provided by the operator. The following figure provides an illustrative overview of the implementation of these coverage areas, where the pink circles would represent the locations of the MDFs and the rest of the circles outline DPs associated to different MDFs.
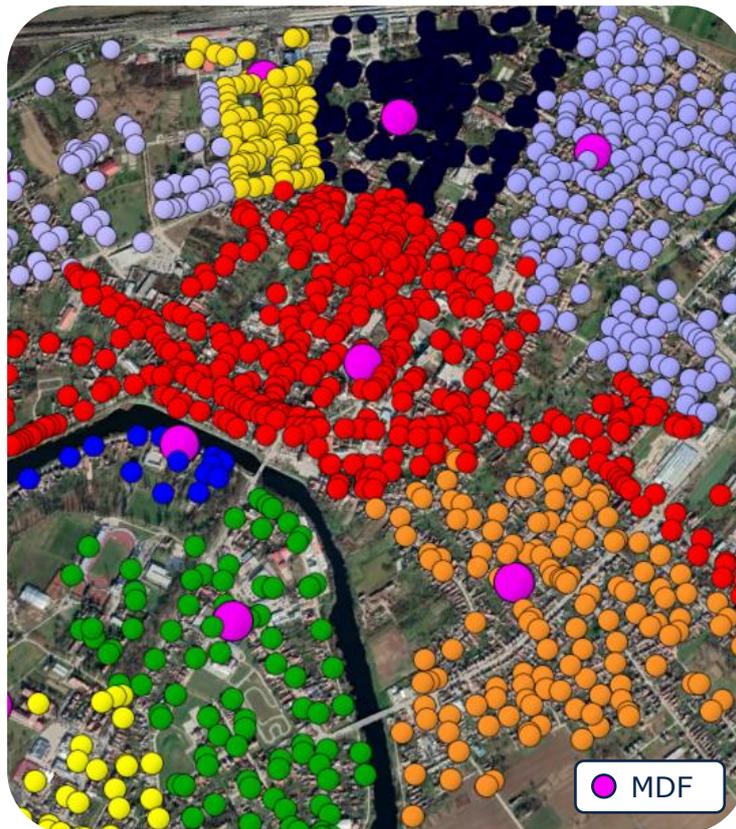
**Exhibit 5.7: Example of assignation of DPs to MDFs**

Once the DP/DN are related to a parent node MDF/ODF, the shortest path calculation is made for every node in each area.

Finally, the total distances between the different network elements can be obtained as the sum of two different sections:

▶ Distances from building to DP/DN (Secondary Network)

▶ Distances from DP/DN to MDF/ODF (Primary Network)

It is important to outline that all these steps are carried out separately for the three different network architectures considered in the model, namely the copper network architecture, the fibre (Old FTTA area) network architecture and the fibre (New OND area) network architecture. Further details about these architectures are provided in section 6.1 of this document.

## 5.3. Outputs treatment

Based on all the information extracted from previous steps, the last stage consists in processing these data in order to be usable in the BULRIC Model. As explained in previous

sections, the geographical modelling provides results at "geotype" level. Thus, before the treatment of the data, these geotypes should be defined.

## 5.3.1 Definition of geotypes

The geotypes are defined based on three different sets of classifications:

▶ County: One of the twenty-one counties in Croatia.

▶ Degree of urbanisation: Depending on the building density, the geotypes are divided into "Urban", "Suburban" or "Rural".

▶ Unbundling status: Depending on the actual unbundling status of the covered area, geotypes are divided into "Unbundled" or "Not-unbundled".

The characterisation of each of the aforementioned classifications is further detailed below.

### *Step 1. County*

The first geotype classification used is related to the different counties in Croatia. There are 21 different counties in the country:

▶ Zagrebacka Zupanija

▶ Krapinsko Zagorska Zupanija

▶ Sisacko Moslavacka Zupanija

▶ Karlovacka Zupanija

▶ Varazdinska Zupanija

▶ Koprivnicko Krizevacka Zupanija

▶ Bjelovarsko Bilogorska Zupanija

▶ Primorsko Goranska Zupanija

▶ Licko Senjska Zupanija

▶ Viroviticko Podravska Zupanija

▶ Pozesko Slavonska Zupanija

▶ Brodsko Posavska Zupanija

▶ Zadarska Zupanija

▶ Osjecko Baranjska Zupanija

▶ Sibensko Kninska Zupanija

- ▶ Vukovarsko Srijemska Zupanija

- ▶ Splitsko Dalmatinska Zupanija

- ▶ Istarska Zupanija

- ▶ Dubrovacko Neretvanska Zupanija

- ▶ Medimurska Zupanija

- ▶ Grad Zagreb

In this case, each building is assigned to its corresponding county based on its location.

### *Step 2. Degree of urbanisation*

Based on the available information at sector level across the country, we have proceeded to classify all MDF coverage areas into geotypes. The number of geotypes has been set to 3 in order to represent three different types of areas: Urban, Suburban and Rural.

The geotype definition has been performed through a cluster analysis. This cluster exercise is carried out by means of a "k-means" algorithm, considering two main variables that have been selected to characterize the geotypes:

- ▶ Buildings density (buildings/km$^2$), i.e. the number of buildings by area.

- ▶ Household density (households/building), i.e. the average number of households per building.

This process has comprised a set of steps:

1. Calculating cluster variables. The buildings density and average number of households per building have been calculated at MDF level. The source of information employed for this calculation has been the data request sent by HT and the buildings database of the DGU[4].

2. Scaling both variables. Before performing the cluster exercise, both variables have been scaled.

3. Executing k-means algorithm. The algorithm of Hartigan and Wong (1979)[5] is used by default.

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[4] DGU (Državna geodetska uprava or State Geodetic Administration): https://dgu.gov.hr/
[5] "A K-Means Clustering Algorith", by J. A. Hartigan and M. A. Wong. More details in: https://www.labri.fr/perso/bpinaud/userfiles/downloads/hartigan_1979_kmeans.pdf

4. Assignation of obtained clusters to each MDF area. Once the three clusters have been calculated, they are assigned to their associated areas.

Based on this, we observed the following characterisation of the different existing Main Distribution Frames areas:
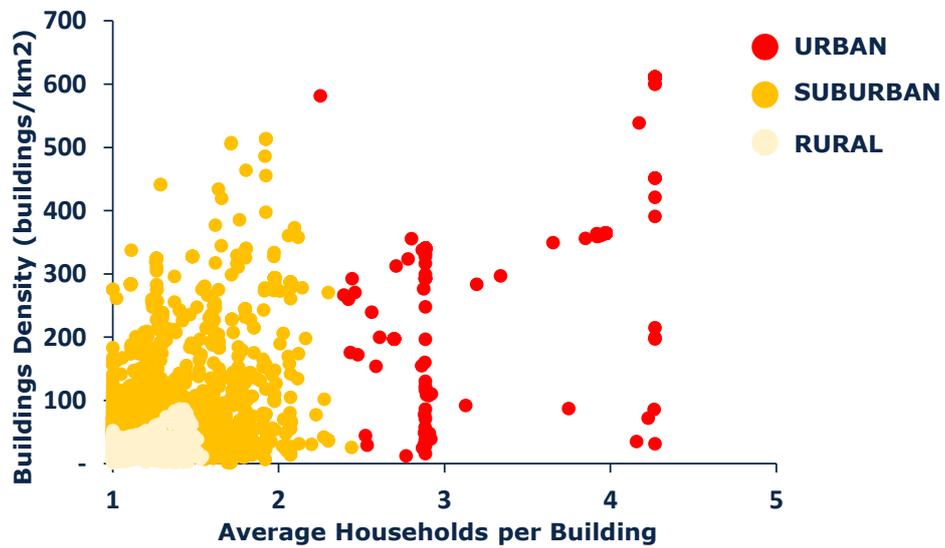


**Exhibit 5.8: Characterisation of the main distribution frames areas into geotypes [Source:Axon Consulting]**

Following the characterisation described, the exhibit below shows the results of the geotype characterisation:
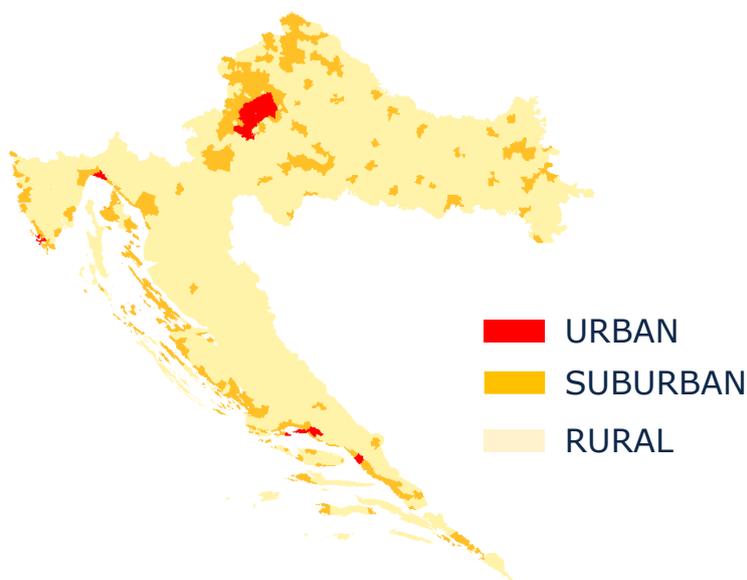
**Exhibit 5.9: Classification into geotypes of Croatia coverage areas for the geographical analysis [Source: Axon Consulting]**

As it can be extracted from the exhibit, more dense areas in the country are classified as urban geotype whereas less populated regions are identified as rural.

### Step 3. Unbundling status

Finally, the disaggregation between unbundled and non-unbundled areas is also considered for urban and suburban regions, where rural areas are set as non-unbundled areas.

This disaggregation is based on the latest status reported of the existing nodes, where HT indicated the node locations where currently alternative operators are co-located, related to unbundled MDF areas.

Therefore, the model is able to calculate the costs stemming from unbundled and non-unbundled areas separately.

The characterization in terms of geotypes allows differentiating a total of 105 in the Croatian territory, in particular, 5 geotypes (urban-unbundled, urban-non-unbundled, suburban-unbundled, suburban-non-unbundled and rural) per 21 counties. However, not all geotypes will contain households, as for instance, there may be counties that do not present any region considered as Urban.

## 5.3.2 Aggregation of information

The last step consists in aggregating the information calculated in the geographical modelling for each of the 105 geotypes defined in the Croatian territory, as explained in the previous section.

The information calculated contains the routes distances between the different network elements, however a greater disaggregation is necessary. The information needed contains, among others, routes distances, type of routes (aerial or underground with/without duct), percentage of sharing between different network sections, etc. which is later used in the BULRIC model for the dimensioning and costing of the cable and network elements required. For this reason, extra treatment of the data is needed.

Knowing all the necessary information about the position of the network elements in the access network as described in section 5.2, the next step consists of the characterisation of the links between them, since these links may be sequentially aggregated so as to save digging, ducting, and cabling costs. An illustrative representation of these aggregations is provided in the exhibit below:
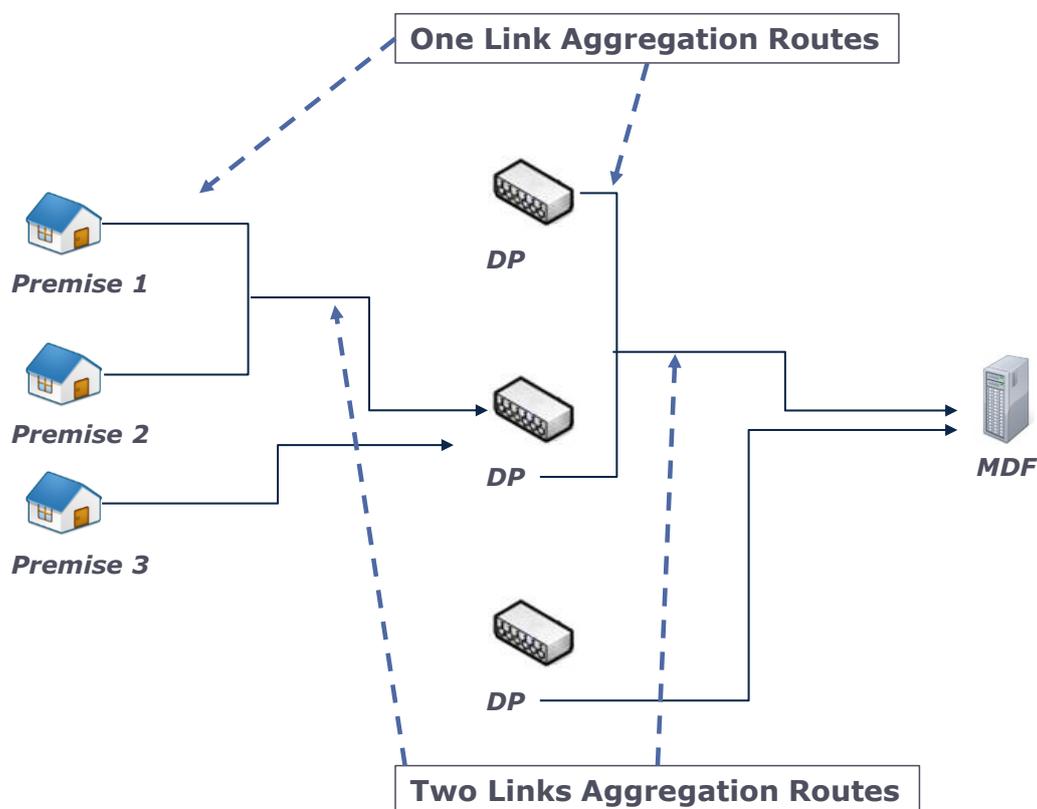


Exhibit 5.10:  Illustrative representation of the connection of network elements

As the modelled operator manages different access networks (copper and fibre) and the inputs needed in the model are different for both access technologies, the calculation is divided in two different blocks.

### *Copper Network*

The first step is to divide the sections into different aggregation links. This division is made at two different levels, for the primary and the secondary network. The steps carried out for this calculation are detailed below, and are the same for both network levels:

1. The routes are assigned to a specific geotype according to its location.

2. The routes are disaggregated in sections with a specific ID, and are classified according to the type of route (aerial, underground directly buried and underground ducted)

3. The number of links per section represents the number of times that the different routes coming from the buildings pass through that specific section in their way until the assigned node in each case.

4. The sections are classified according to the number of aggregation links they have, and the total distance of these sections is calculated.

The following table illustrates an example of results extracted from the geographical analysis which will be taken as inputs in the BULRIC model.

| Section | Units | Description | Grad Zagreb – Urban – Unbundled | Grad Zagreb – Urban – Not Unbundled |
|---|---|---|---|---|
| Aggregation of 1 link | metres | | 460.797 | 328.964 |
| Aggregation of 2 links | metres | | 196.515 | 139.859 |
| Aggregation of 3 links | metres | | 106.434 | 78.709 |
| Aggregation of 4 links | metres | | 64.441 | 51.590 |
| Aggregation of 5 links | metres | | 45.155 | 37.953 |
| Aggregation of 6 links | metres | | 32.807 | 27.927 |
| Aggregation of 7 links | metres | | 24.291 | 21.148 |
| Aggregation of 8 links | metres | Secondary aerial routes | 17.967 | 15.768 |
| Aggregation of 9 links | metres | | 16.092 | 13.450 |
| Aggregation of 10 links | metres | | 12.746 | 10.213 |
| Aggregation of 11 links | metres | | 10.074 | 7.001 |
| Aggregation of 12 links | metres | | 8.008 | 7.088 |
| Aggregation of 13 links | metres | | 6.612 | 5.579 |
| Aggregation of 14 links | metres | | 4.637 | 6.063 |
| Aggregation of more than 14 links | metres | | 44.045 | 46.895 |
| Aggregation of 1 link | metres | | 59.200 | 31.872 |
| Aggregation of 2 links | metres | | 21.258 | 13.266 |
| Aggregation of 3 links | metres | | 10.239 | 6.387 |
| Aggregation of 4 links | metres | | 7.593 | 4.701 |
| Aggregation of 5 links | metres | | 6.783 | 5.315 |
| Aggregation of 6 links | metres | | 4.046 | 2.614 |
| Aggregation of 7 links | metres | Secondary routes that are buried directly (without ducts) | 3.304 | 2.352 |
| Aggregation of 8 links | metres | | 7.031 | 3.055 |
| Aggregation of 9 links | metres | | 1.893 | 2.272 |
| Aggregation of 10 links | metres | | 1.201 | 1.520 |
| Aggregation of 11 links | metres | | 888 | 1.743 |
| Aggregation of 12 links | metres | | 831 | 1.486 |
| Aggregation of 13 links | metres | | 1.152 | 1.097 |
| Aggregation of 14 links | metres | | 674 | 625 |
| Aggregation of more than 14 links | metres | | 10.444 | 16.244 |
| Aggregation of 1 link | metres | | 265.614 | 68.785 |
| Aggregation of 2 links | metres | | 72.728 | 19.432 |
| Aggregation of 3 links | metres | | 33.804 | 9.830 |
| Aggregation of 4 links | metres | | 15.448 | 4.860 |
| Aggregation of 5 links | metres | | 9.986 | 2.724 |
| Aggregation of 6 links | metres | | 6.269 | 4.892 |
| Aggregation of 7 links | metres | Secondary routes that are buried employing ducts | 5.931 | 3.533 |
| Aggregation of 8 links | metres | | 19.107 | 1.935 |
| Aggregation of 9 links | metres | | 7.497 | 1.032 |
| Aggregation of 10 links | metres | | 2.467 | 654 |
| Aggregation of 11 links | metres | | 1.545 | 610 |
| Aggregation of 12 links | metres | | 1.333 | 426 |
| Aggregation of 13 links | metres | | 1.121 | 713 |
| Aggregation of 14 links | metres | | 424 | 417 |
| Aggregation of more than 14 links | metres | | 5.687 | 12.125 |

**Exhibit 5.11: Example of input about distances for copper [Source: Axon Consulting]**

Furthermore, the distances of routes that are shared between the secondary network and the primary network are calculated and included in the model as a percentage over the secondary network distances.

| Shared routes | Units | Grad Zagreb – Urban – Unbundled | Grad Zagreb – Urban – Not Unbundled |
|---|---|---|---|
| Percentage of shared routes | % | 41% | 42% |

**Exhibit 5.12: Example of input about shared routes [Source: Axon Consulting]**

*Fibre Network*

In the case of fibre, inputs are divided in two different groups depending on the architecture design used by the operator.

▶ Old FTTA Areas

▶ New ODN Areas

Further details about these designs are provided in section 6.1.

The inputs for Old FTTA Areas are calculated following the same steps than those described for copper network.

For the new ODN Areas, which is the new deployment method used by the operator, the inputs needed present a difference: the distances per link are divided in different deployment steps per geotype.

Since the fibre technology is currently being rolled-out in these areas, the determination of links distances has been divided in different deployment steps per geotype to be able to capture in a more realistic manner the future deployment faced by the modelled operator.

For this purpose, the households and the corresponding route distances are assigned to different deployment steps (with ranges of 10% coverage), following the rules explained in next paragraphs.

First of all, the ODFs have been ordered according to the shortest average route distance per household, except for currently active ODFs that have been considered to be passed in the first place. For the classification inside the ODFs, the order for covering households is the following:

1. Already covered households based on the reality of HT's covered areas

2. Households that are not covered yet and which are associated to currently existing Distribution Nodes

3. Households that are not covered yet and which are associated to Distribution Nodes that will be deployed in the future, classified by the shortest average route distance required per household, for connecting the household until the ODF

Once the households have been classified, they are assigned to a specific deployment step (in ranges of 10% of coverage as shown below) and the same method explained for copper

networks is repeated for each deployment step defined, taking into account the different sections of the access network (primary and secondary).

| Geotype | Section | Units | From 0% to 10% | From 10% to 20% | From 20% to 30% | From 30% to 40% | From 40% to 50% | From 50% to 60% | From 60% to 70% | From 70% to 80% | From 80% to 90% | From 90% to 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grad Zagreb - Urban - Unbundled | Aggregation of 1 link | metres | 6.187 | 11.099 | 53.664 | 96.914 | 61.083 | 78.035 | 105.649 | 47.901 | 49.189 | 221.504 |
| | Aggregation of 2 links | metres | 2.872 | 4.842 | 18.607 | 32.849 | 23.210 | 26.328 | 47.132 | 18.022 | 20.268 | 77.625 |
| | Aggregation of 3 links | metres | 843 | 3.064 | 12.863 | 17.673 | 13.125 | 14.292 | 25.758 | 8.494 | 10.451 | 38.924 |
| | Aggregation of 4 links | metres | 449 | 1.032 | 7.445 | 9.849 | 9.952 | 9.085 | 15.155 | 6.489 | 6.659 | 27.388 |
| | Aggregation of 5 links | metres | 403 | 1.854 | 6.035 | 5.791 | 6.511 | 7.340 | 12.926 | 4.304 | 7.490 | 20.019 |
| | Aggregation of 6 links | metres | 254 | 814 | 4.537 | 6.298 | 4.814 | 5.934 | 9.290 | 3.137 | 3.479 | 15.356 |
| | Aggregation of 7 links | metres | 167 | 935 | 3.239 | 4.126 | 3.754 | 4.231 | 7.613 | 3.553 | 2.978 | 12.368 |
| | Aggregation of 8 links | metres | 244 | 943 | 4.980 | 3.056 | 3.090 | 3.700 | 7.967 | 1.998 | 3.267 | 8.708 |
| | Aggregation of 9 links | metres | 99 | 986 | 2.361 | 2.784 | 3.824 | 3.273 | 5.578 | 2.344 | 3.100 | 8.565 |
| | Aggregation of 10 links | metres | 350 | 512 | 1.805 | 3.419 | 2.205 | 2.648 | 4.004 | 1.670 | 2.146 | 7.857 |
| | Aggregation of 11 links | metres | 277 | 655 | 1.610 | 3.017 | 2.130 | 1.802 | 3.813 | 1.251 | 1.783 | 6.730 |
| | Aggregation of 12 links | metres | 178 | 149 | 1.475 | 3.709 | 2.320 | 2.269 | 3.035 | 1.596 | 2.042 | 5.684 |
| | Aggregation of 13 links | metres | 208 | 245 | 1.741 | 1.776 | 1.553 | 2.171 | 3.507 | 1.086 | 1.630 | 5.661 |
| | Aggregation of 14 links | metres | 258 | 299 | 956 | 1.181 | 1.173 | 1.431 | 2.244 | 1.313 | 1.201 | 3.598 |
| | Aggregation of more than 14 links | metres | 3.284 | 16.703 | 17.039 | 42.207 | 25.739 | 32.223 | 32.695 | 22.411 | 22.307 | 85.558 |

**Exhibit 5.13: Example of input about distances for fibre [Source: Axon Consulting]**

Please note that the same steps deployment classification is done for determining the number of ODF, DNs and DPs.

# 6. Dimensioning Module

The Dimensioning Module aims at designing the network and calculating the number of network resources required to serve the demand and coverage levels of the reference operator. This section has been divided in three different network sections which are described in detail below:

▶ Access Network Dimensioning (geotype dependant)

▶ Transmission Network Dimensioning (geotype independent)

▶ Core Network Dimensioning (geotype independent)

## 6.1. Access Network Dimensioning (geotype dependant)

The Access Network Module aims at designing the cable for the access network and calculating the number of network resources required to serve the demand and coverage levels of the reference operator at geotype level. This process is performed in the block 6 of the Model.

In order to better understand this dimensioning procedure, the following exhibit provides an illustrative overview of the network architecture that is being modelled, together with the nomenclature employed for the different elements:
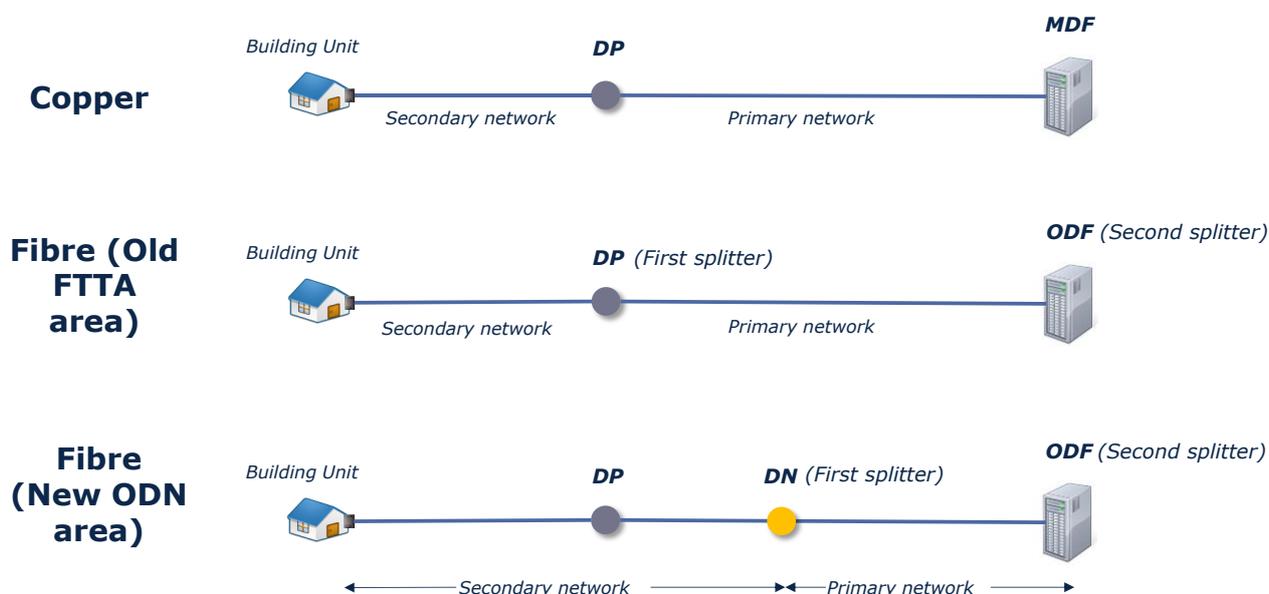


**Exhibit 6.1: Architecture of the modelled Access Network [Source: Axon Consulting]**

It is important to clarify that the Exhibit 6.1 shows the three different network architectures that are used in the model:

▶ **Copper network architecture**. The access network comprises the network elements ranging from the users' households to the MDF level. In between, the following network elements may be identified:

- **In-building (Drop cable)**: Represents the copper cables located inside the building and connecting the customer household to the operator's network. Note that this element has been modelled as number of units instead of cable length.

- **Secondary Network:** Represents the section of the copper network connecting the Building Unit to the DP. This includes the copper cables as well as the physical infrastructure required for their accommodation (trenches, ducts, manholes, etc.).

- **Distribution Point (DP)**: Represents the box installed for the first aggregation of copper cables coming from the building units.

- **Primary Network:** Represents the section of the copper network connecting the DP and the MDF. This includes the copper cables as well as the physical infrastructure required for their accommodation (trenches, ducts, manholes, etc.).

- **Main Distribution Frame (MDF):** Constitutes the local office in the access network, which contains the second aggregation point of copper cables coming from the DPs. It contains both the MDFs and the MSANs.

▶ **Fibre (Old FTTA area) network architecture.** It is worth noting that this is the design that was employed by the reference operator during the first years of deployment of fibre networks. This access network comprises the network elements ranging from the users' households to the ODF level. In between, the following network elements may be identified:

- **In-building (Drop cable)**: Represents the fibre cables located inside the building and connecting the customer household to the operator's network. Note that this element has been modelled as number of units instead of cable length.

- **Secondary Network:** Represents the section of the fibre network connecting the Building Unit to the DP. This includes the fibre cables as well as the physical infrastructure required for their accommodation (trenches, ducts, manholes, etc.).

- **Distribution Point (DP)**: Represents the box installed for the first aggregation of fibre cables coming from the building units. This point also contains the first splitter of the fibre network.

- **Primary Network:** Represents the section of the fibre network connecting the DP and the ODF. This includes the fibre cables as well as the physical infrastructure required for their accommodation (trenches, ducts, manholes, etc.).

- **Optical Distribution Frame (ODF):** Constitutes the local office in the access network, which contains the second aggregation point of fibre cables coming from the DPs. This point contains the second splitter of the fibre network, as well as the ODFs and the OLTs.

▶ **Fibre (New OND area) network architecture.** It is worth noting that this is the design that is currently employed by the reference operator for the deployment of fibre networks. After the introduction of HAKOM's Symmetrical Regulations, the operator needed to install an additional element in the network: Distribution Node (further details below). This access network comprises the network elements ranging from the users' households to the ODF level. In between, the following network elements may be identified:

- **In-building (Drop cable)**: Represents the fibre cables located inside the building and connecting the customer household to the operator's network. Note that this element has been modelled as number of units instead of cable length.

- **Distribution Point (DP)**: Represents the box installed for the first aggregation of fibre cables coming from the building units. No splitter is installed in this point.

- **Secondary Network:** Represents the section of the fibre network connecting the Building Unit to the DN. This includes the fibre cables as well as the physical infrastructure required for their accommodation (trenches, ducts, manholes, etc.).

- **Distribution Node (DN)**: Represents the box installed for the second aggregation of fibre cables coming from the DPs. This point also contains the first splitter of the fibre network.

- **Primary Network:** Represents the section of the fibre network connecting the DN and the ODF. This includes the fibre cables as well as the physical infrastructure required for their accommodation (trenches, ducts, manholes, etc.).

- **Optical Distribution Frame (ODF):** Constitutes the local office in the access network, which contains the third aggregation point of fibre cables coming from the DNs. This point contains the second splitter of the fibre network, as well as the ODFs and the OLTs.

Based on the above described network architecture, the signal flows from the households to the DP and it is directed to the MDF/ODF.

The dimensioning of the access network is performed in the model separately for each of the geotypes considered, to accurately reflect the impact of the geographical characteristics in the deployment. This dimensioning approach has been divided into the following different blocks, namely:

▶ Dimensioning of the copper network

▶ Dimensioning of the fibre network

▶ Dimensioning of the civil infrastructure elements

Each of the following sections provide further details on the technical algorithms employed in each case.

### 6.1.1 Copper network

The dimensioning of the copper network is organised into six blocks, as shown in the chart below.

| 1. Buried copper cable |
|:---:|
| 2. Aerial copper cable |
| 3. Distribution Points |
| 4. MDFs |
| 5. Joints |
| 6. MSAN |
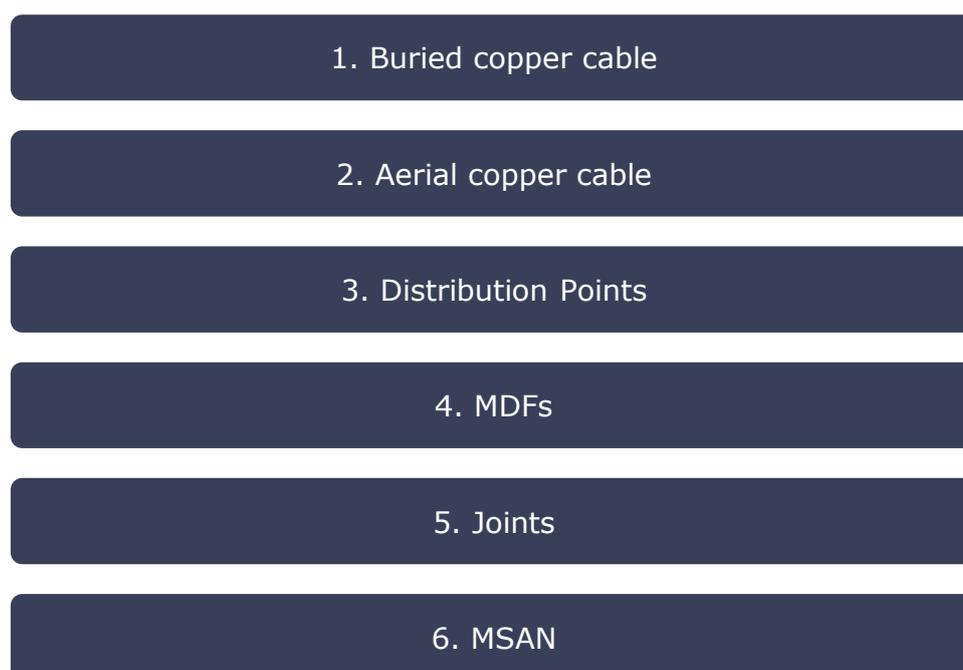
**Exhibit 6.2: Schematic steps for the dimensioning of copper network elements [Source: Axon Consulting]**

#### *Step 1: Buried Copper Cable*

The first step consists in calculating the total kilometres of copper cable which is located underground. These calculations are separated in two physical sections, according to each network segment (see Exhibit 6.1 for the Architecture of the Network):

▶ Secondary network – From Building unit to DP

▶ Primary network – From DP to MDF

The outputs of the geographical analysis (see section 5) are taken as inputs to calculate the kilometres of copper in the access network.

*Secondary network – From Building unit to DP*

The following exhibit illustrates the methodology followed for the buried copper cable in the secondary network:
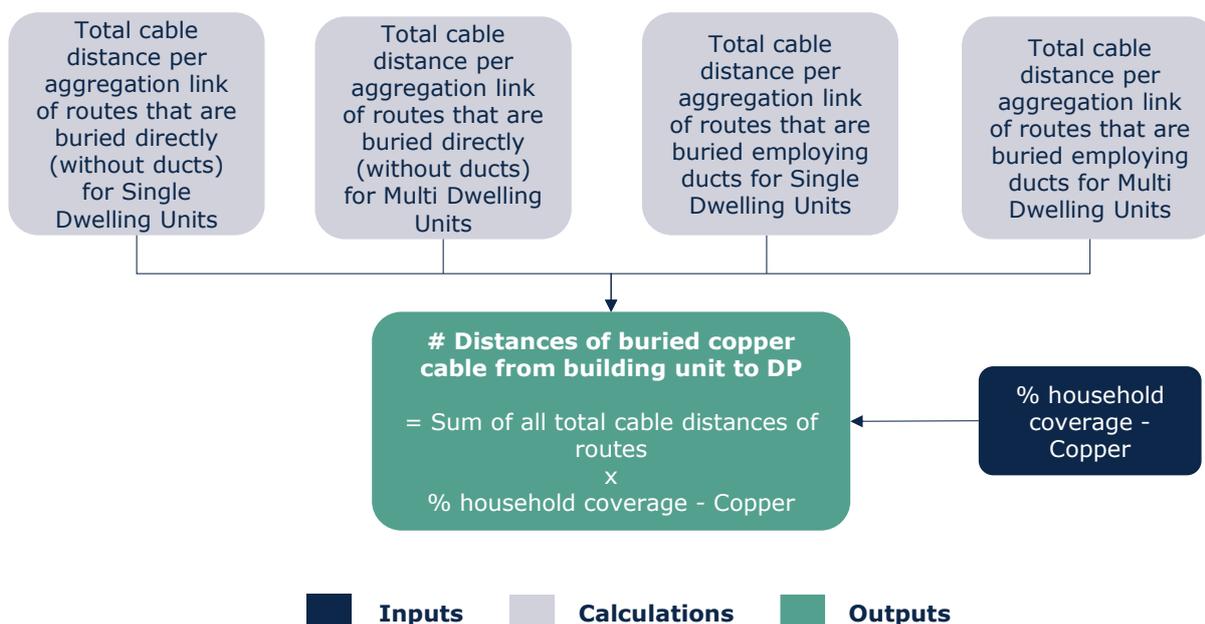


**Exhibit 6.3: Algorithm for calculating the kilometres of copper cable in the secondary network [Source: Axon Consulting]**

The parameters "Total cable distance per aggregation link" come from the results obtained in the geographical analysis, and it provides information about the distances in the access network section for the different aggregations of links. The following exhibit shows an illustrative example about how the aggregation of links can be performed in the network.
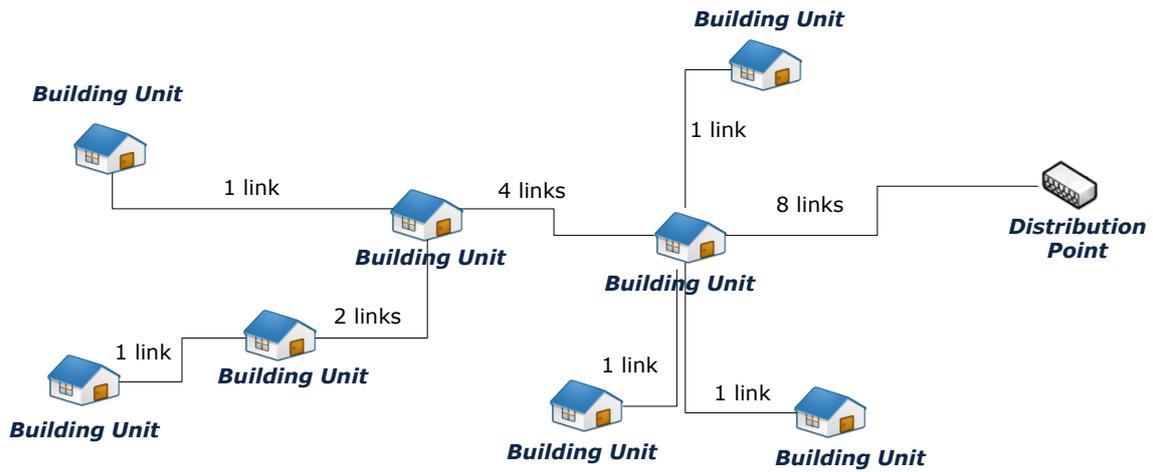
**Exhibit 6.4: Illustrative example of aggregation links [Source: Axon Consulting]**

An illustrative example of the calculation for the aggregation of links, step-by-step, is provided below:

| Number of aggregated links between Building Units and DPs | Total route distance (km) [A] | Number of copper pairs required[6] [B] | Cable size employed[7] (copper pairs) [C] | Number of cables required [D] | Total route distance associated to each cable size configuration[8] (km) [E] = [A] x [D] |
|---|---|---|---|---|---|
| Aggregation of 1 link | 7,75 | 1 | 1 | 1 | 7,75 (of 1 pair) |
| Aggregation of 2 links | 8,50 | 2 | 5 | 1 | 8,50 (of 5 pairs) |
| Aggregation of 3 links | 8,97 | 3 | 5 | 1 | 8,97 (of 5 pairs) |
| Aggregation of 4 links | 8,92 | 4 | 5 | 1 | 8,92 (of 5 pairs) |
| Aggregation of 5 links | 8,59 | 5 | 5 | 1 | 8,59 (of 5 pairs) |
| Aggregation of 6 links | 8,00 | 6 | 10 | 1 | 8,00 (of 10 pairs) |
| Aggregation of 7 links | 7,18 | 7 | 10 | 1 | 7,18 (of 10 pairs) |
| Aggregation of 8 links | 6,65 | 8 | 10 | 1 | 6,65 (of 10 pairs) |
| Aggregation of 9 links | 5,68 | 9 | 10 | 1 | 5,68 (of 10 pairs) |
| Aggregation of 10 links | 4,98 | 10 | 10 | 1 | 4,98 (of 10 pairs) |
| Aggregation of 11 links | 4,42 | 11 | 10 | 2 | 8,84 (of 10 pairs) |
| Aggregation of 12 links | 3,85 | 12 | 10 | 2 | 7,70 (of 10 pairs) |
| Aggregation of 13 links | 3,27 | 13 | 10 | 2 | 6,54 (of 10 pairs) |
| Aggregation of 14 links | 2,94 | 14 | 10 | 2 | 5,88 (of 10 pairs) |
| Aggregation of more than 15 links | 19,88 | 15 | 10 | 2 | 39,76 (of 10 pairs) |
| TOTAL | 109,58 | - | - | - | 143,94 |

**Exhibit 6.5: Example of the calculation for the aggregation of links [Source: Axon Consulting]**

As it can be extracted from above, the final distance of copper cable associated to a certain aggregation of links [E] are calculated taking into account the total route distance for such aggregation [A] and multiplied by the number of cables required [D] for the needed configuration [reflected in C].

It is important to note that even if in the table presented above, the total distance of copper cable (143,94 kilometres) has been considered as a whole, this calculation is

---

[6] This parameter is equivalent to the number of aggregated links (1, 2, 3, 4, …) multiplied by 1 in the case of Single Dwelling Units (as each Building Unit contains only one household) and by the number of households/dwellings per Building Unit in the case of Multi Dwelling Units (as each Building Unit contains several households/dwellings). This specific example shown in the table is referred to a case of Single Dwelling Units.

[7] Note that configurations of 1, 5 and 10 copper pairs are available in this example.

[8] In number of available copper pairs.

performed in the model individually for each configuration of cables (in terms of number of copper pairs).

The above calculation is performed four times, for the different cases:

▶ Routes that are buried directly (without ducts) for Single Dwelling Units

▶ Routes that are buried directly (without ducts) for Multi Dwelling Units

▶ Routes that are buried employing ducts for Single Dwelling Units

▶ Routes that are buried employing ducts for Multi Dwelling Units

Finally, the distances calculated for each of these four cases are combined as shown in Exhibit 6.3.

*Primary network – From DP to MDF*

For the copper cable length in the primary network, calculations are identical to those performed in the secondary network (see above), taking into account that:

▶ Distances per number of aggregated links are different and specific for this section of the network. More specifically, distances between Building Units and DP are now replaced by distances between the DP and the MDF to reflect the primary network segment.

▶ Only two calculations are needed (instead of four), one for 'Routes that are buried directly (without ducts)' and other for 'Routes that are buried employing ducts', since the distinction between Single and Multi Dwelling Units is not relevant at this stage of the network.

*Total buried network*

The total distance of buried copper cable is calculated as the sum of distances in the secondary and primary network, calculated in previous paragraphs.

### Step 2: Aerial Copper Cable

The second step consists in calculating the total kilometres of copper cable which is located aerial. These calculations are similar to those presented in the previous section for buried copper cable. They are also separated in two physical sections, according to each network segment (see Exhibit 6.1 for the Architecture of the Network):

▶ Secondary network – From Building unit to DP

▶ Primary network – From DP to MDF

The outputs of the geographical analysis (see section 5) are taken as inputs to calculate the kilometres of copper in the access network.

*Secondary network – From Building unit to DP*

The following exhibit illustrates the methodology followed for the aerial copper cable in the secondary network:
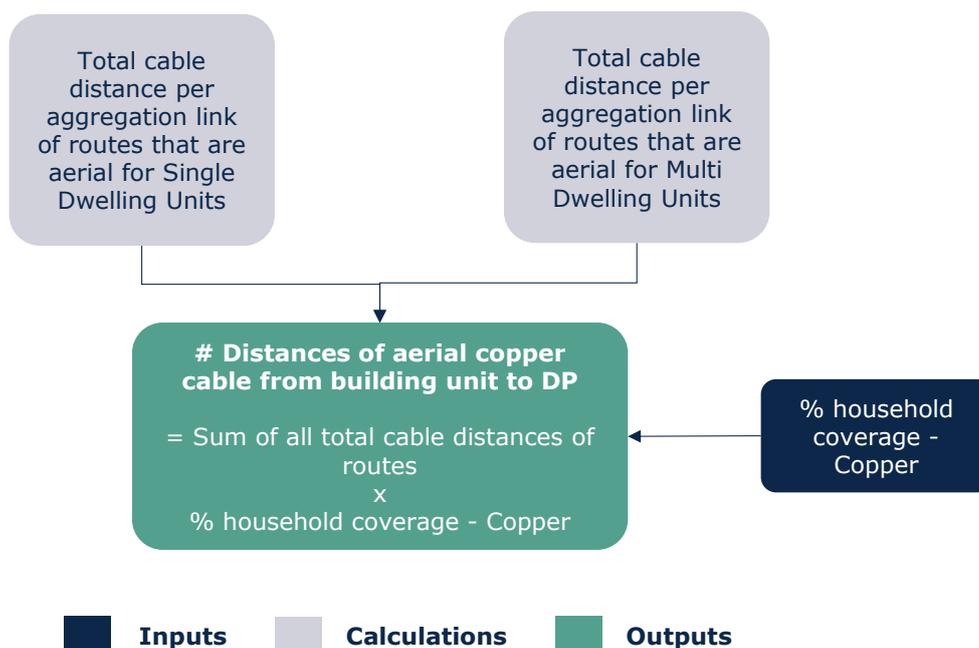


**Exhibit 6.6: Algorithm for calculating the kilometres of copper cable in the secondary network [Source: Axon Consulting]**

The parameters "Total cable distances per aggregation link" come from the results obtained in the geographical analysis, in an equivalent manner to those for buried copper cable, described in the previous section.

*Primary network – From DP to MDF*

For the copper cable length in the primary network, the calculations are identical to those performed in the secondary network (see above), taking into account that:

▶ Distances per number of aggregated links are different and specific for this section of the network. More specifically, distances between Building Units and DP are now replaced by distances between the DP and the MDF to reflect the primary network segment.

▶ Only one calculation is needed (instead two), since the distinction between Single and Multi Dwelling Units is not relevant at this stage of the network.

*Total aerial network*

The total distance of aerial copper cable is calculated as the sum of distances in the secondary and primary network, calculated in previous paragraphs.

### Step 3: Distribution Points (DPs)

The number of distribution points depending on the size are calculated according to the algorithm outlined below:
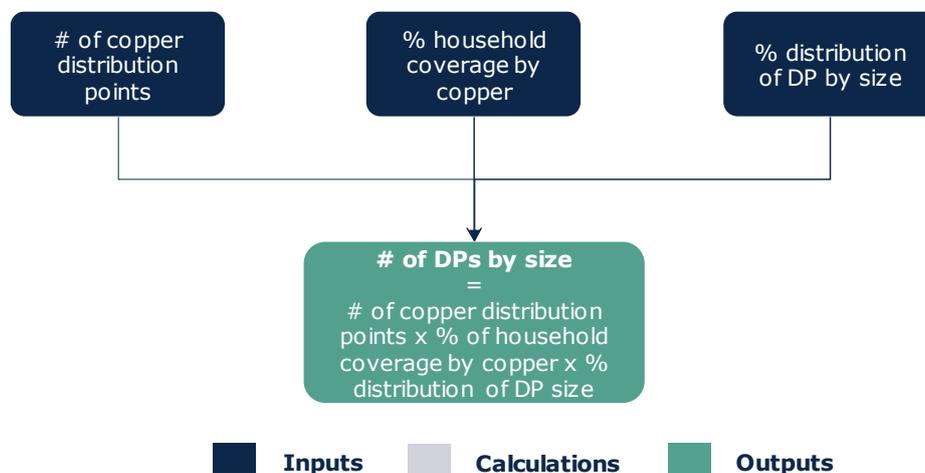


**Exhibit 6.7: Algorithm for calculating the number of copper DPs by size [Source: Axon Consulting]**

The number of copper DPs is multiplied by the copper coverage and by the percentage of DPs depending on the size, obtaining the corresponding number of DPs by size.

## Step 4: Main Distribution Frames (MDFs)

The number of MDFs depending on the size and the number of copper and FTTC/FTTN sites are calculated according to the algorithm outlined below:
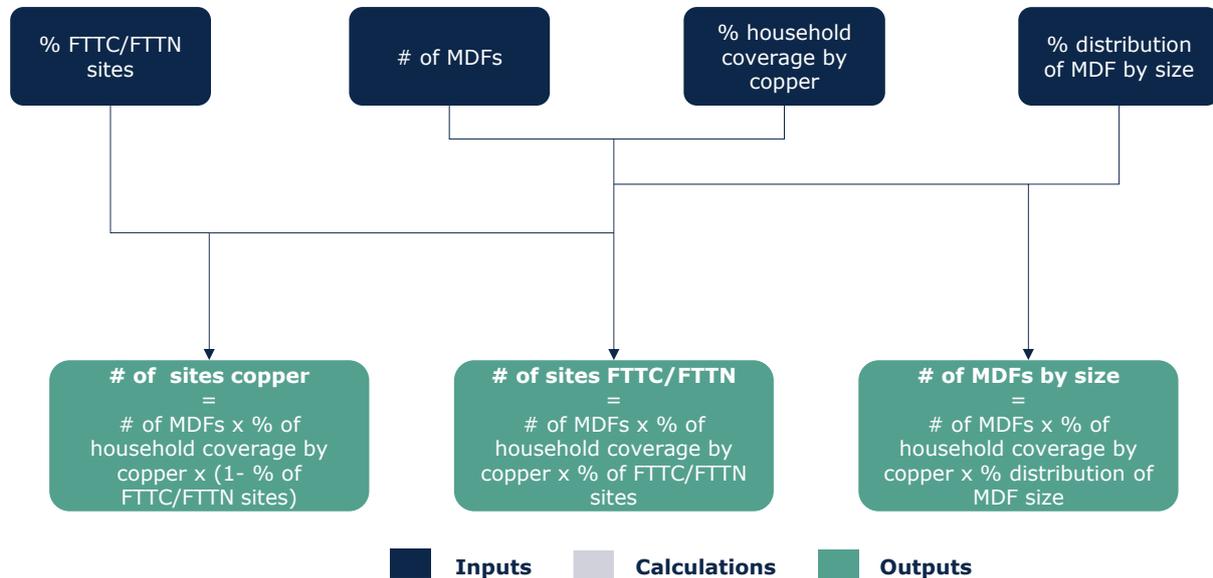


**Exhibit 6.8: Algorithm for calculating the number of MDFs by size and the number of copper and FTTC/FTTN sites [Source: Axon Consulting]**

The number of MDFs is multiplied by the copper coverage and by the percentage of MDFs depending on the size, obtaining the corresponding number of MDFs by size.

On the other hand, in order to obtain the number of copper or FTTC/FTTN sites, the product of the number of MDFs and copper coverage is multiplied by the percentage of copper and FTTC/FTTN sites, respectively.

## Step 5: Joints

The number of joints is calculated according to the algorithm outlined below:
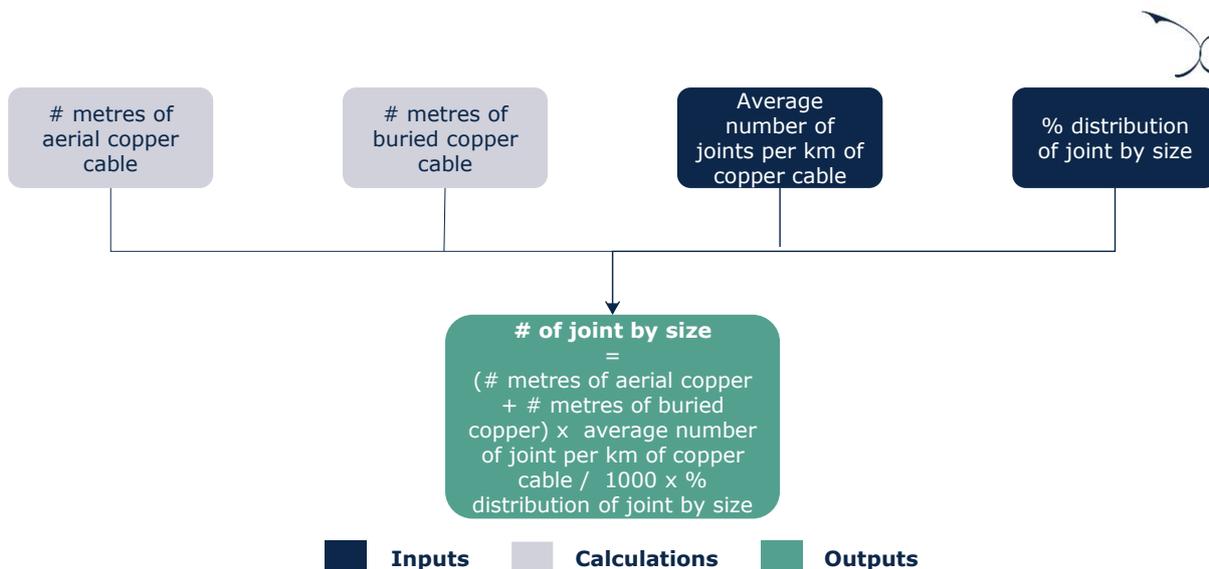
**Exhibit 6.9: Algorithm for calculating the number of joints by size [Source: Axon Consulting]**

The total distance of copper cable (aerial and buried) is multiplied by the average number of joints per km of copper cable and by the percentage of joints depending on the size, obtaining the total number of joints required by size.

### Step 6: MSANs

The number of MSAN cards is calculated according to the algorithm outlined below:
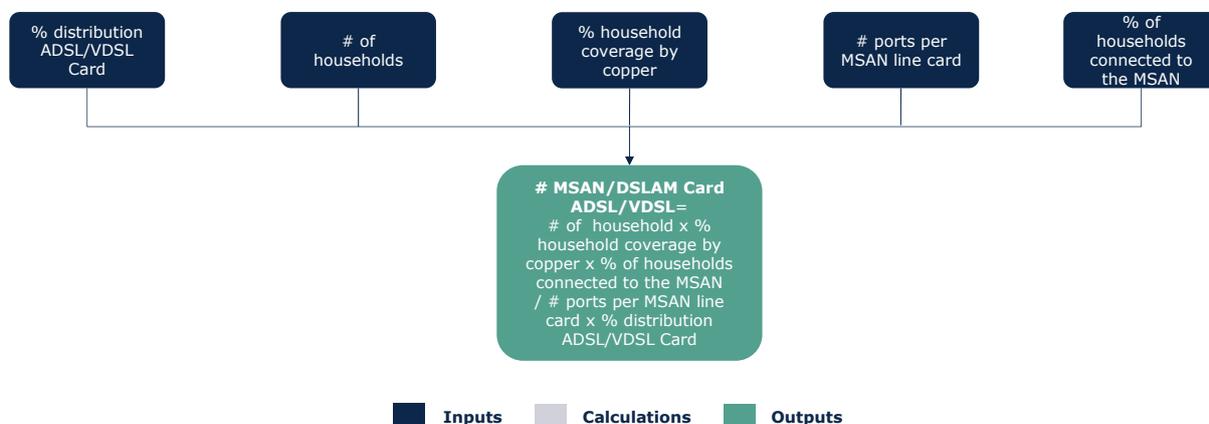


**Exhibit 6.10: Algorithm for calculating the number of MSAN cards [Source: Axon Consulting]**

The total number of households is multiplied by the copper coverage and by percentage of households connected to the MSAN. This calculation is then divided by the number of ports per MSAN line card and finally, the result is multiplied by the percentages of ADSL cards and VDSL cards, obtaining the total number of MSAN ADSL Cards and the number of MSAN VDSL cards, respectively.

Finally, the number of MSAN associated to broadband services is calculated as the number of cards calculated in the previous paragraph divided by the maximum number of line cards per MSAN rack, and excluding the portion of racks related to POTS cards (addressed to voice-only customers).

## 6.1.2 Fibre network

The dimensioning of the fibre cable is organised into nine blocks, as shown in the chart below.

| |
|---|
| 1. Buried fibre cable |
| 2. Aerial fibre cable |
| 3. DPs |
| 4. DNs |
| 5. ODFs |
| 6. Joints |
| 7. Splitters |
| 8. OLTs |
| 9. Building installation |
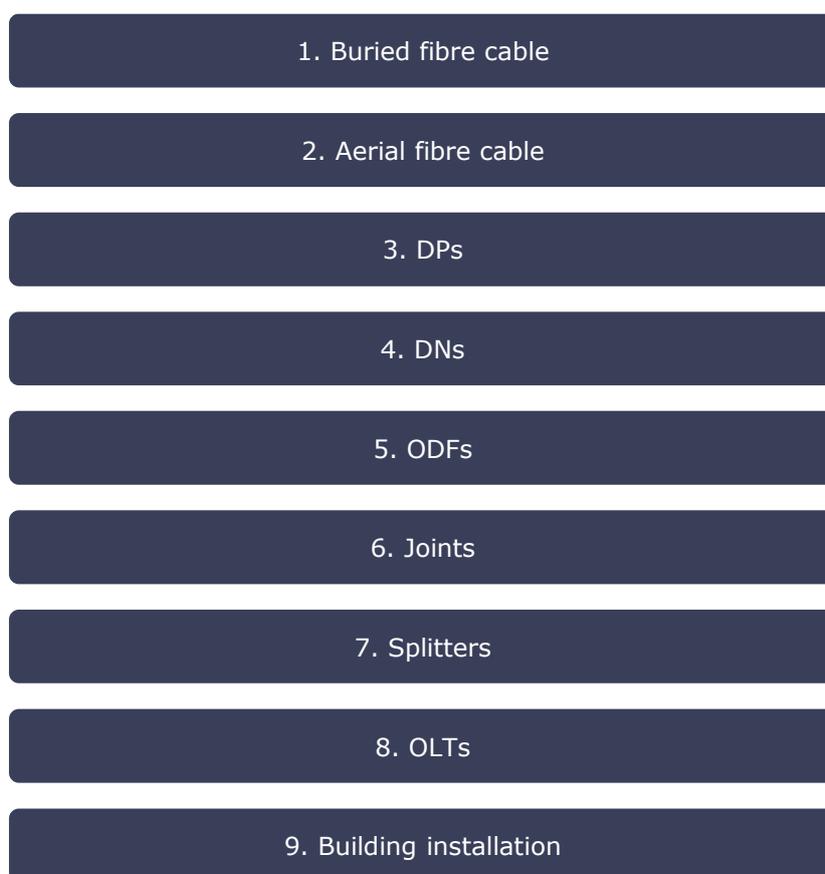
**Exhibit 6.11: Schematic steps for the dimensioning of the fibre network elements [Source: Axon Consulting]**

### *Step 1: Buried Fibre Cable*

The first step consists in calculating the total kilometres of fibre cable which is located underground. These calculations are separated in two physical sections for the two different design of fibre networks, according to each network segment (see Exhibit 6.1 for the Architecture of the Network):

▶ Secondary network – From Building unit to DN (ODN Area)

▶ Primary network – From DN to ODF (ODN Area)

▶ Secondary network – From Building unit to DP (Old FTTA Area)

▶ Primary network – From DP to ODF (Old FTTA Area)

The outputs of the geographical analysis (see section 5) are taken as inputs to calculate the kilometres of fibre in the access network.

*Secondary network – From Building unit to DN (ODN Area)*

The following exhibit illustrates the methodology followed for the buried fibre cable in the secondary network of ODN Areas:
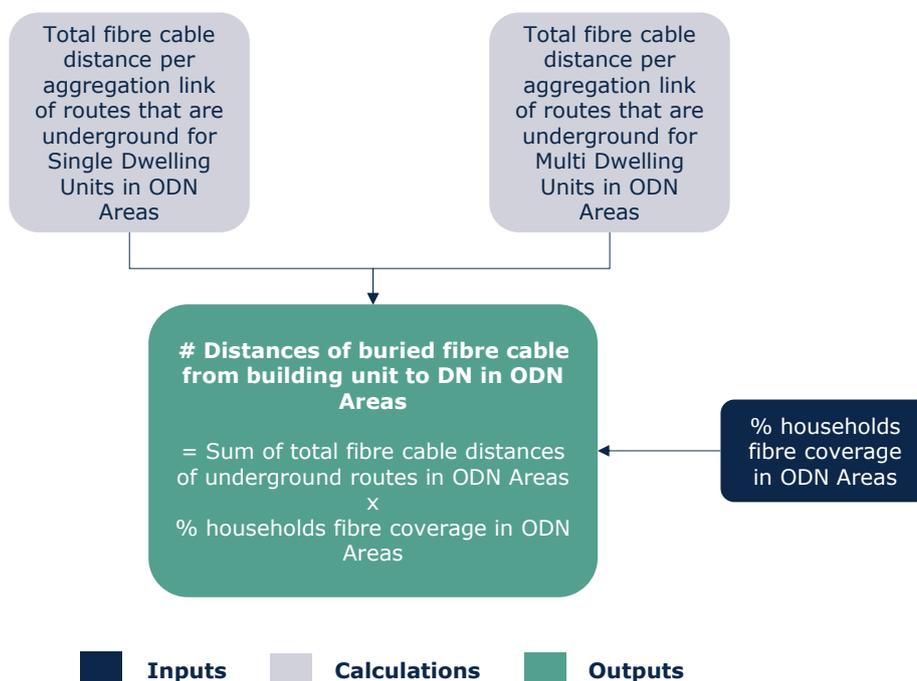


**Exhibit 6.12: Algorithm for calculating the kilometres of fibre cable in the secondary network [Source: Axon Consulting]**

In an equivalent manner to the copper network, the parameters "Total fibre cable distance per aggregation link" come from the results obtained in the geographical analysis, and it provides information about the distances in the access network section for the different aggregations of links.

More specifically, the calculation of aggregations of links is equivalent to that in copper networks but taking into account that:

▶ The concept of copper pair is replaced by the concept of fibre strand. In other words, configurations of copper cables defined by means of the number of copper pairs are

replaced by configurations available of fibre cables defined by means of the number of fibre strands.

▶ In the specific cases of ODN Areas for fibre networks, inputs related to distances have been defined in the model for different ranges of coverage with steps of 10%, as illustrated in the following exhibit:

| Section | Units | ODN AREAS | | | | | | | | | | Total |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | From 0% to 10% | From 10% to 20% | From 20% to 30% | From 30% to 40% | From 40% to 50% | From 50% to 60% | From 60% to 70% | From 70% to 80% | From 80% to 90% | From 90% to 100% | |
| Aggregation of 1 link | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 2 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 3 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 4 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 5 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 6 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 7 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 8 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 9 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 10 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 11 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 12 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 13 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of 14 links | metres | - | - | - | - | - | - | - | - | - | - | - |
| Aggregation of more than 14 link | metres | - | - | - | - | - | - | - | - | - | - | - |

**Exhibit 6.13: Example of the definition of inputs in the model for fibre distances in ODN Areas [Source: Axon Consulting]**

As the deployment of ODN Areas is currently being performed (is still on-going) by the reference operator, it is important to reflect in the model that the profile of the distances required for covering a certain geotype is not homogeneous throughout the entire territory covered by such geotype. In other words, depending on the range of households covered, distances required are different, as typically, in a new roll-out, first ranges refer to those areas that present a higher density of households and therefore this is translated into a lower unitary cable distance per household.

When looking at the table above, the first range "From 0% to 10%" gathers the routes distances that are necessary to cover the first 10% of households within the geotype. In a similar way, the second range "From 10% to 20%" gathers the routes distances that are necessary to cover the second 10% of households within the geotype. The same applies to all ranges, until reaching the last range "From 90% to 100%". Also in this line, it is important to indicate that the sum of distances of all ranges of the table provides the total routes distances needed for covering the analysed geotype.

As a way of example, if for a certain year the model assumes 33% of fibre coverage in ODN Areas, the route distance required for that year corresponds to the sum of distances in the three first ranges ("From 0% to 10%", "From 10% to 20%" and "From 20% to 30%") plus the 30%[9] of the distance of the fourth range ("From 30% to 40%").

---

[9] Calculated as the missing 3% (33%-30%) of coverage and multiplied by the step of a range (10%).

*Primary network – From DN to ODF (ODN Area)*

For the fibre cable length in the primary network in ODN Areas, calculations are identical to those performed in the secondary network (see above), taking into account that:

▶ Distances per number of aggregated links are different and specific for this section of the network. More specifically, distances between Building Units and DN are now replaced by distances between the DN and the ODF to reflect the primary network segment.

▶ Only one calculation is needed (instead of two) since the distinction between Single and Multi Dwelling Units is not relevant at this stage of the network.

▶ The process of selection of the necessary fibre cable configurations takes into account the splitting that is performed at the DN level. In particular, as a splitter is placed in the DN level, this entails that various of the fibre strands coming from the households are aggregated into a unique fibre strand at this point in the network. In particular, the splitting factor assumed in this point of the network is 32:1.

*Secondary network – From Building unit to DP (Old FTTA Area)*

The following exhibit illustrates the methodology followed for the buried fibre cable in the secondary network of Old FTTA Areas:
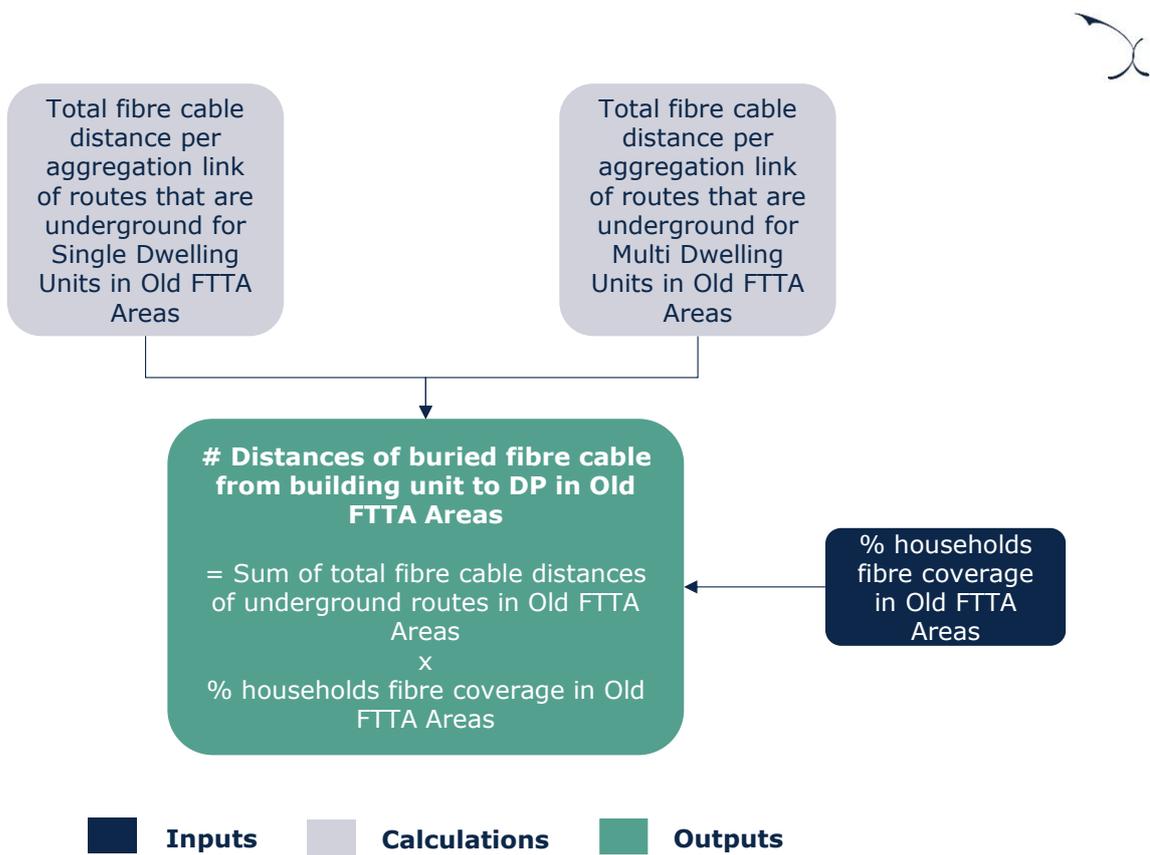
**Exhibit 6.14: Algorithm for calculating the kilometres of fibre cable in the secondary network [Source: Axon Consulting]**

The process followed is identical to that performed in the ODN Areas (see above), taking into account that:

▶ Distances per number of aggregated links are different and specific for this type of areas. It is also important to note that, as the roll-out of the Old FTTA Areas is already completed (this design is not used anymore), there is no need of reflecting difference ranges of coverage for the distances routes, and thus, a unique column is necessary for the input, as shown in the following exhibit:

| Section | Units | Total route distance |
|---|---|---|
| Aggregation of 1 link | metres | - |
| Aggregation of 2 links | metres | - |
| Aggregation of 3 links | metres | - |
| Aggregation of 4 links | metres | - |
| Aggregation of 5 links | metres | - |
| Aggregation of 6 links | metres | - |
| Aggregation of 7 links | metres | - |
| Aggregation of 8 links | metres | - |
| Aggregation of 9 links | metres | - |
| Aggregation of 10 links | metres | - |
| Aggregation of 11 links | metres | - |
| Aggregation of 12 links | metres | - |
| Aggregation of 13 links | metres | - |
| Aggregation of 14 links | metres | - |
| Aggregation of more than 14 links | metres | - |

**Exhibit 6.15: Example of the definition of inputs in the model for fibre distances in Old FTTA Areas [Source: Axon Consulting]**

▶ The DP is replaced by the DN, as no DN exists in the Old FTTA Areas. The dimensioning also assumes that the splitting factor assumed in this point of the network is 32:1.

*Primary network – From DP to ODF (Old FTTA Area)*

For the fibre cable length in the primary network in Old FTTA Areas, calculations are identical to those performed in the secondary network (see above), taking into account that:

▶ Distances per number of aggregated links are different and specific for this section of the network. More specifically, distances between Building Units and DP are now replaced by distances between the DP and the ODF to reflect the primary network segment.

▶ Only one calculation is needed (instead of two) since the distinction between Single and Multi Dwelling Units is not relevant at this stage of the network.

*Total buried network*

The total distance of buried fibre cable is calculated as the sum of distances in the secondary and primary networks for both ODN and Old FTTA Areas, calculated in previous paragraphs.

**Step 2: Aerial Fibre Cable**

The calculation of aerial fibre cables is identical to that of buried fibre cables (see previous step), considering aerial routes instead of underground routes.

## Step 3: Distribution Points (DPs)

The number of distribution points depending on the size are calculated according to the algorithm outlined below:
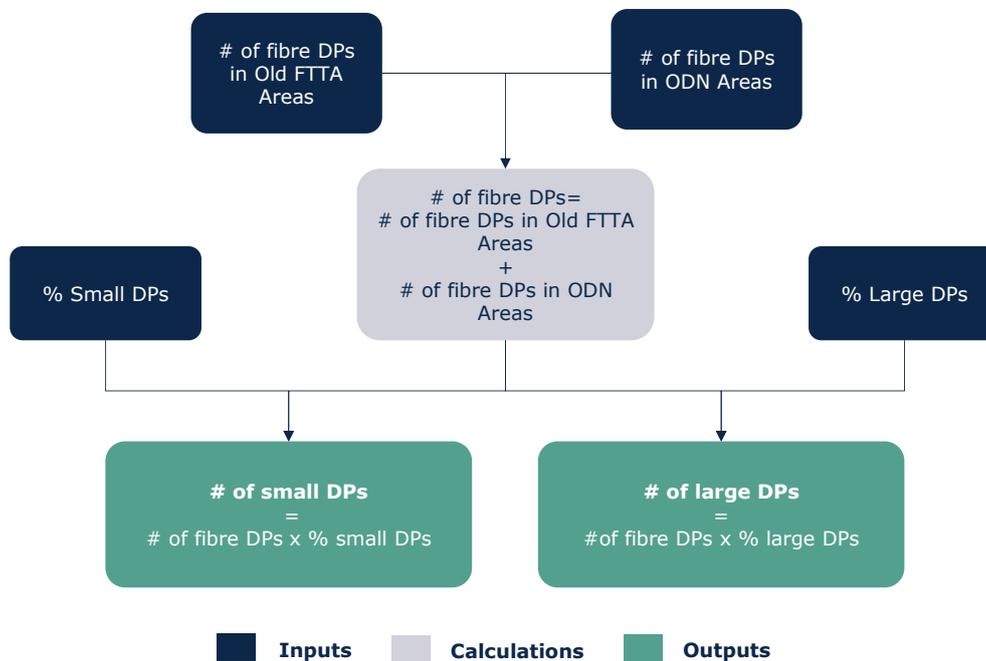


**Exhibit 6.16: Algorithm for calculating the number of fibre DPs by size [Source: Axon Consulting]**

Firstly, for every year, the number of fibre DPs is calculated as the sum of DPs in Old FTTA and ODN Areas. These inputs are directly defined considering the coverage required for the relevant year.

Finally, depending on the size of the fibre DPs (small or large), the number of DPs are multiplied by the percentage of small and large DPs, respectively.

### *Step 4: Distribution Nodes (DNs)*

The number of distribution nodes depending on the number of connections are calculated according to the algorithm outlined below:
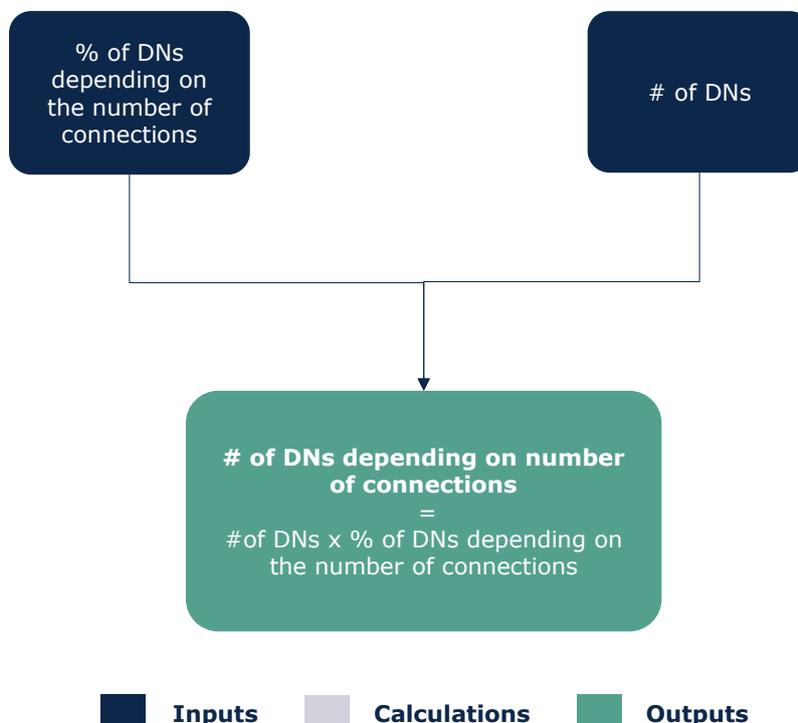


**Exhibit 6.17: Algorithm for calculating the number of DNs by size [Source: Axon Consulting]**

The number of DNs depending on the number of connections, is calculated multiplying the number of DNs for every year (defined directly considering the coverage required for that year) by the percentage of DNs depending on the number of connections.

### *Step 5: Optical Distribution Frames (ODFs)*

The number of optical distribution frames depending on the number of connections are calculated according to the algorithm outlined below:
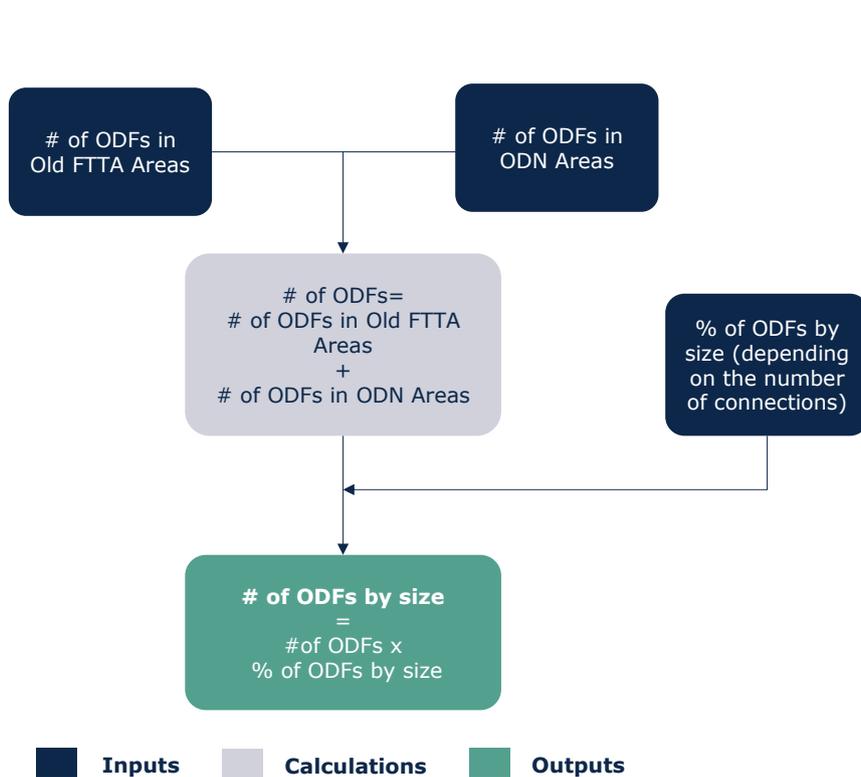
**Exhibit 6.18: Algorithm for calculating the number of ODFs by size [Source: Axon Consulting]**

Firstly, for every year, the number of ODFs is calculated as the sum of ODFs in Old FTTA and ODN Areas. These inputs are directly defined considering the coverage required for each year.

Finally, the number of ODFs is multiplied by the percentage of ODFs by size.

### Step 6: Joints

The number of joints is calculated according to the algorithm outlined below:
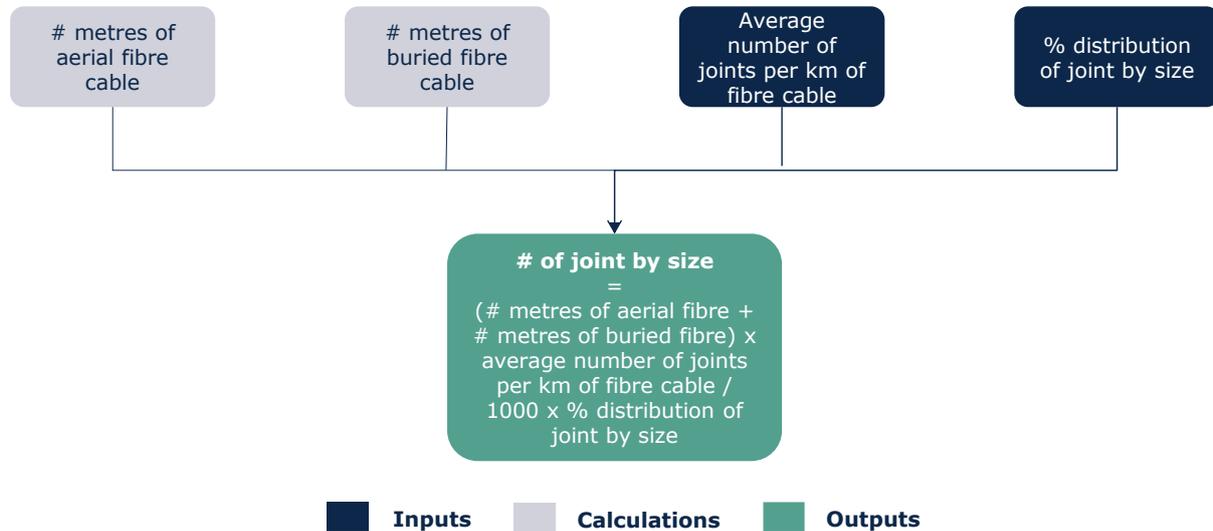
**Exhibit 6.19: Algorithm for calculating the number of joints by size [Source: Axon Consulting]**

The total distance of fibre cable (aerial and buried) is multiplied by the average number of joints per km of fibre cable and by the percentage of joints depending on the size, obtaining the total number of joints required by size.

### Step 7: Splitters

The number of splitters is calculated according to the algorithm outlined below:
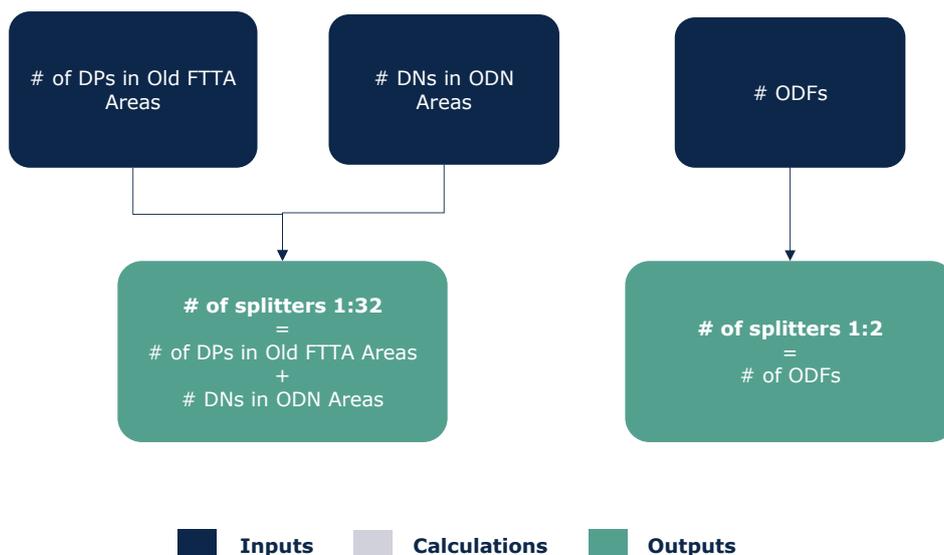
**Exhibit 6.20: Algorithm for calculating the number of splitters [Source: Axon Consulting]**

The number of splitters 1:2 is equal to the number of ODFs calculated in the step 5 for every year.

The calculation of the number of splitters 1:32 is, for every year, the sum of DPs in Old FTTA Areas and the sum of DNs in ODN Areas, as these are the aggregation points where the splitter is located for each type of network design.

Additionally, if the user selects in the CONTROL panel the option "Alternative design (Splitter only located in the ODF level)" for the "Dimensioning rules for fibre networks" scenario, then, the model assumes that in the case of ODN Areas, no splitter is located in the DN.

### Step 8: OLTs

The number of OLTs is calculated according to the algorithm outlined below:
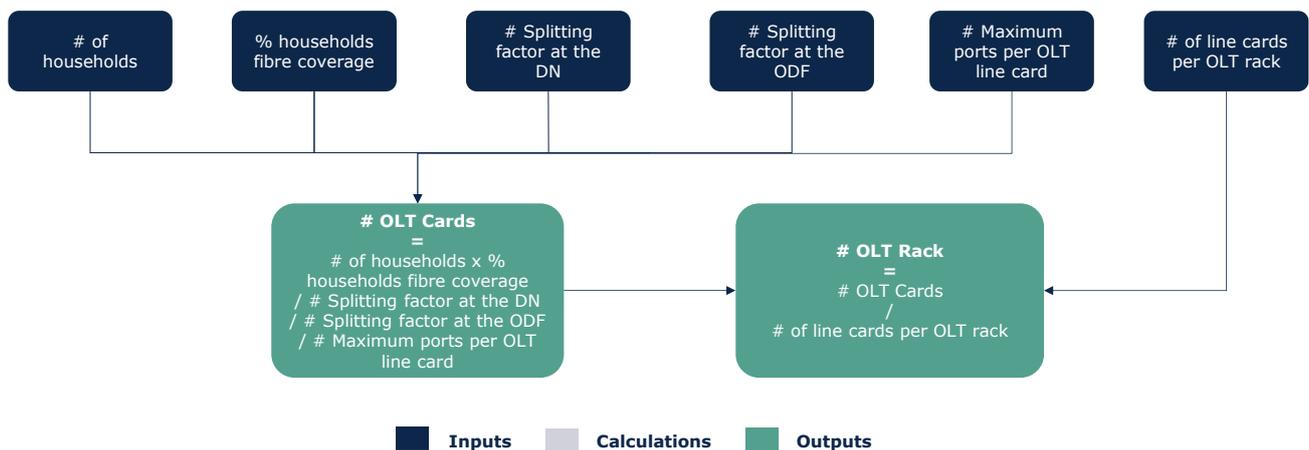


**Exhibit 6.21: Algorithm for calculating the number of OLT Cards and OLT Racks [Source: Axon Consulting]**

The product of the number of households and fibre coverage is divided by the splitting factors (at the DN and the ODF) and by the maximum ports per OLT, obtaining the number of OLT Cards.

Finally, the number of OLT Rack is calculated as the division between the number of OLT Cards and the number of line cards per OLT rack.

## *Step 9: Building Installations*

The number building installation is calculated according to the algorithm outlined below:
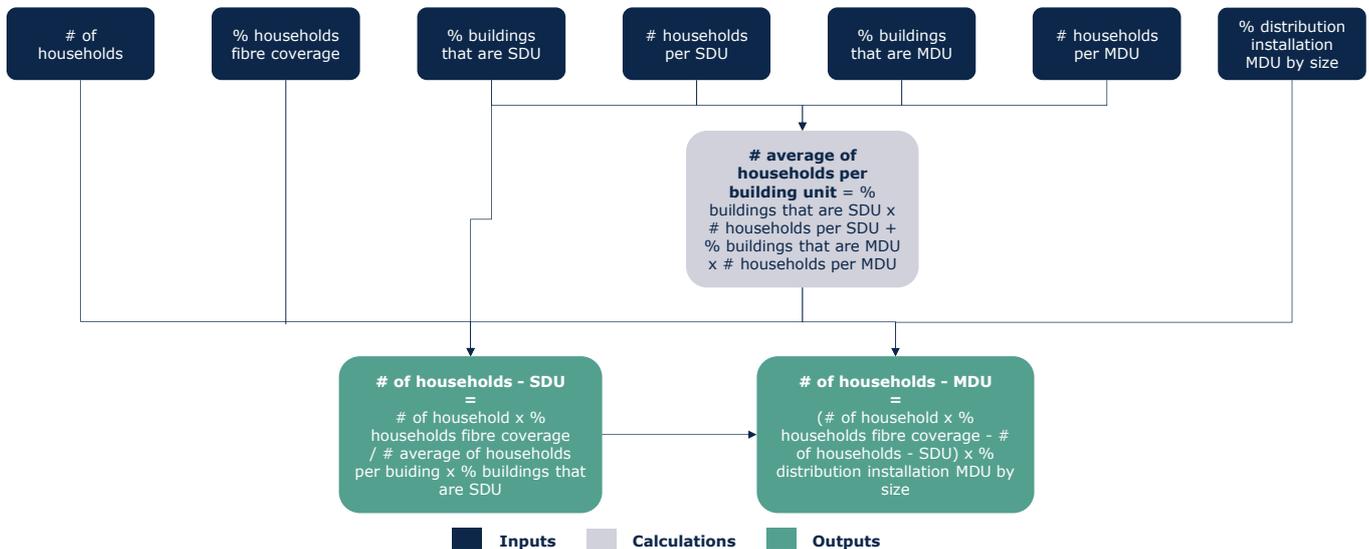


**Exhibit 6.22: Algorithm for calculating the building installation [Source: Axon Consulting]**

Finally, the fibre building installations in single dwelling units (SDU) for which the homeowner has not given permission to perform such installation are excluded from the total.

It is important to highlight that despite its name, the building installation cost has been defined as a cost per household in the model.

## 6.1.3  Civil infrastructure

The dimensioning of the civil infrastructure is organised into three blocks, as shown in the chart below.
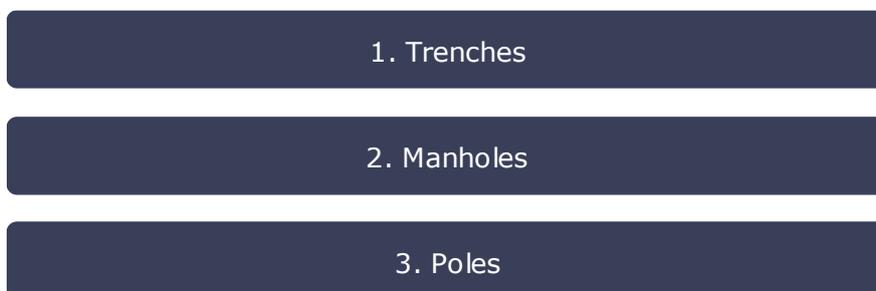


**Exhibit 6.23: Schematic steps for the dimensioning of the infrastructure elements [Source: Axon Consulting]**

***Trenches***

*Copper trenches*

The number of trenches without ducting of the copper network is calculated according to the algorithm outlined below:
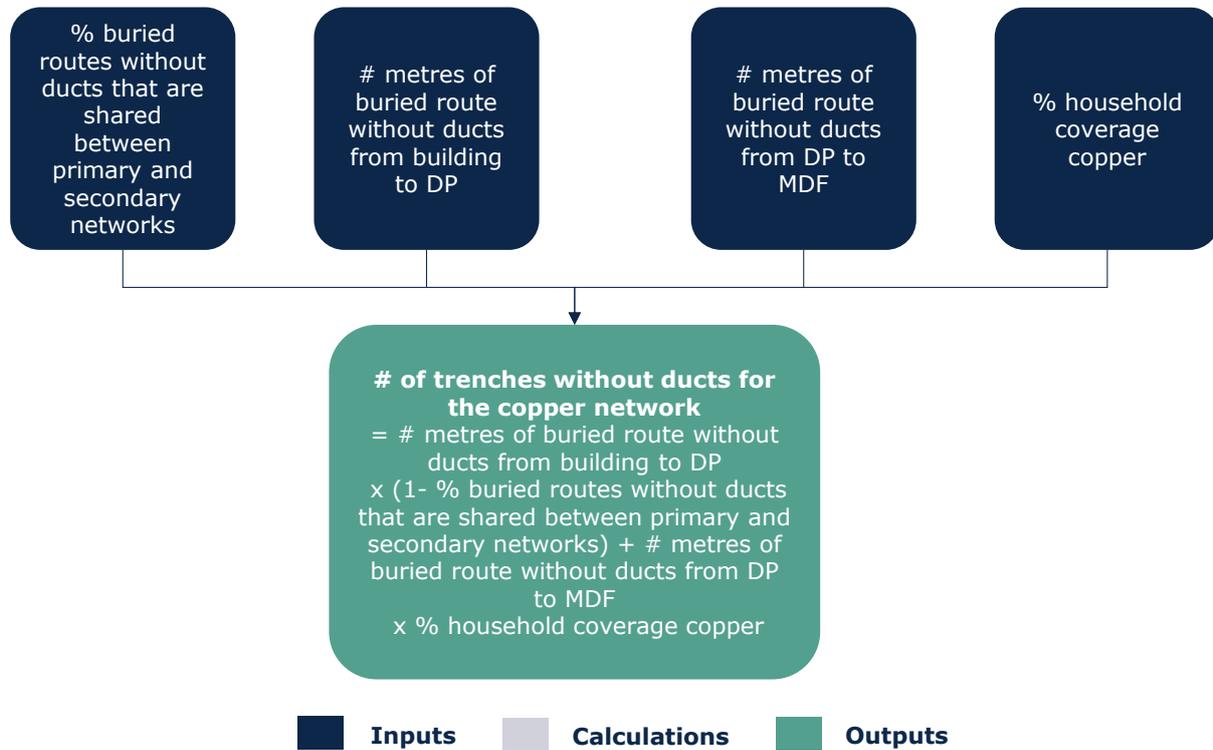


**Exhibit 6.24: Algorithm for calculating the number of tranches without ducting in the copper network [Source: Axon Consulting]**

On the other hand, the number of trenches with ducting of the copper network is calculated according to the algorithm outlined below:
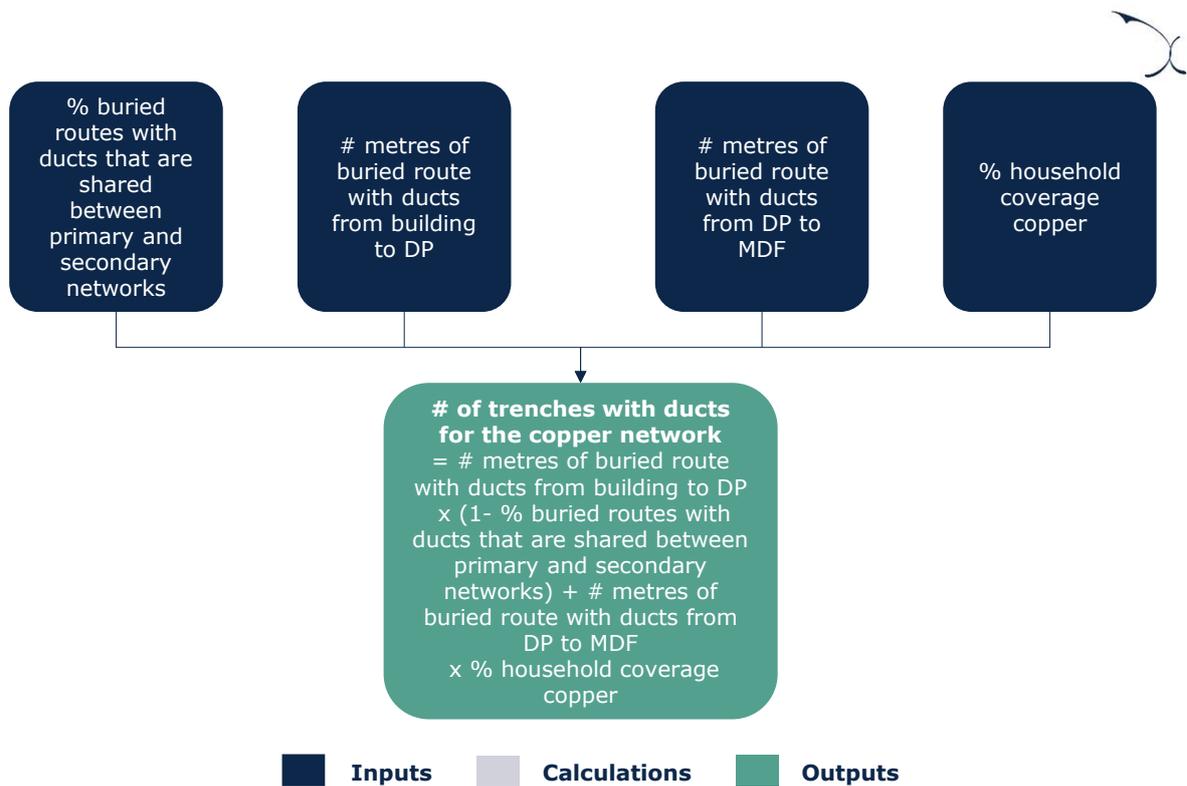
Exhibit 6.25: Algorithm for calculating the number of tranches with ducting in the copper network
[Source: Axon Consulting]

*Fibre trenches*

The calculation of the distances of fibre trenches is performed following the same steps as the copper trenches.

*Shared trenches*

Finally, once the meters of trenches with ducting have been obtained for both copper and fibre networks separately, the model estimates, based on the percentage of shared trenches between both networks, the meters of trenches with ducting shared.

The cost of these trenches is finally allocated between fibre and copper networks by considering the number of active lines of each technology in the corresponding year.

**Manholes**

The number of manholes is calculated according to the algorithm outlined below:
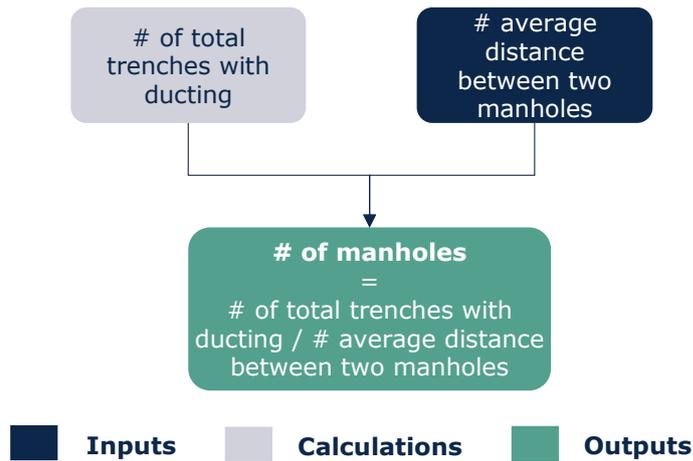
**Exhibit 6.26: Algorithm for calculating the number of manholes [Source: Axon Consulting]**

The meters of total trenches with ducting are divided by the average distance between two manholes, obtaining the number of manholes for each geotype.

The same calculation is performed for copper trenches, fibre trenches and trenches shared between both networks.

Finally, in the case of manholes for trenches shared between both networks, such manholes are split between copper and fibre networks considering the number of active users in the corresponding geotype.

## Poles

The number of poles is calculated according to the algorithm outlined below:
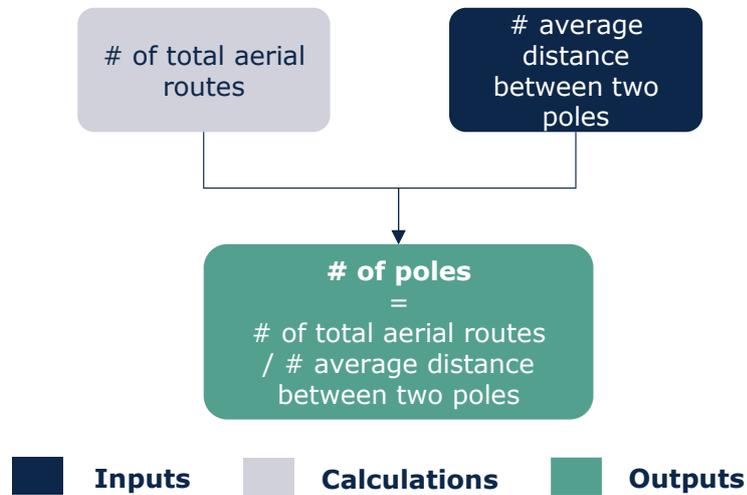


**Exhibit 6.27: Algorithm for calculating the number of poles [Source: Axon Consulting]**

The meters of total aerial routes are divided by the average distance between two poles, obtaining the number of poles for each geotype.

The same calculation is performed for the different types of aerial routes: aerial copper routes, aerial fibre routes and aerial routes shared between both networks.

Finally, in the case of poles for routes shared between both networks, such poles are split between copper and fibre networks considering the number of active users in the corresponding geotype.

## 6.2. Transmission Network Dimensioning (geotype independent)

The Transmission module is responsible for dimensioning the required interconnections of equipment that occur between the access and core network. This module dimensions all the links from the local or regional nodes to the core nodes, as well as the connections in between these. This process is performed at the beginning (block 1) of the worksheet '7A CALC DIM CORE´ of the Model.

The transmission network modelled may be divided into two main type of networks:

▶ WDM network

▶ IP/MPLS network

Each of the following sections provide further details on these types of networks.

## 6.2.1 WDM network

The WDM network of the modelled operator is structured as shown in the following illustrative representation:
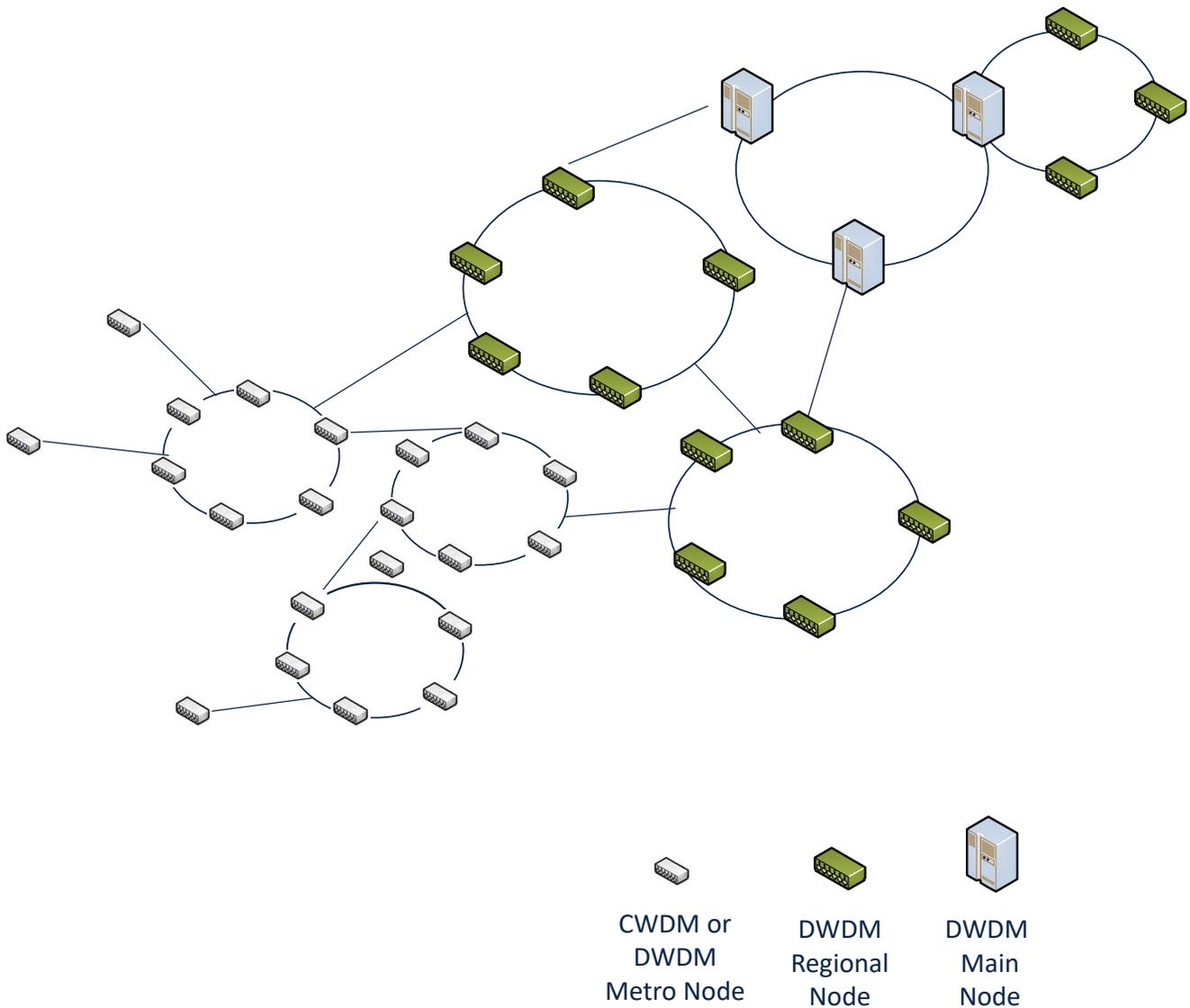


**Exhibit 6.28: Overview of the general architecture considered in the WDM network [Source: Axon Consulting]**

In light of the above structure, transmission links are divided in the following categories:

▶ *CWDM or DWDM Metro Links*

▶ *DWDM Regional Links*

▶ *DWDM Main Links*

The dimension of the transmission links has been optimised taking into consideration the position of the operators' network elements. Specifically, information provided by operators have been taken to determine the different links in the country in terms of length.

The dimensioning of the transmission links selects the cheapest configuration available that is able to handle the link's traffic.

The percentage of traffic that will circulate through each link is introduced based on the percentage of active premises for which the associated traffic will need to circulate through that link.

### Step 1. Calculation of CWDM or DWDM Metro Links

As a first step, the model calculates the number of links that would be required under each configuration, based on their bitrate. Knowing the number of links required, the Model then calculates their associated costs, and selects the most cost-efficient alternative among those available, as shown in the illustration below:
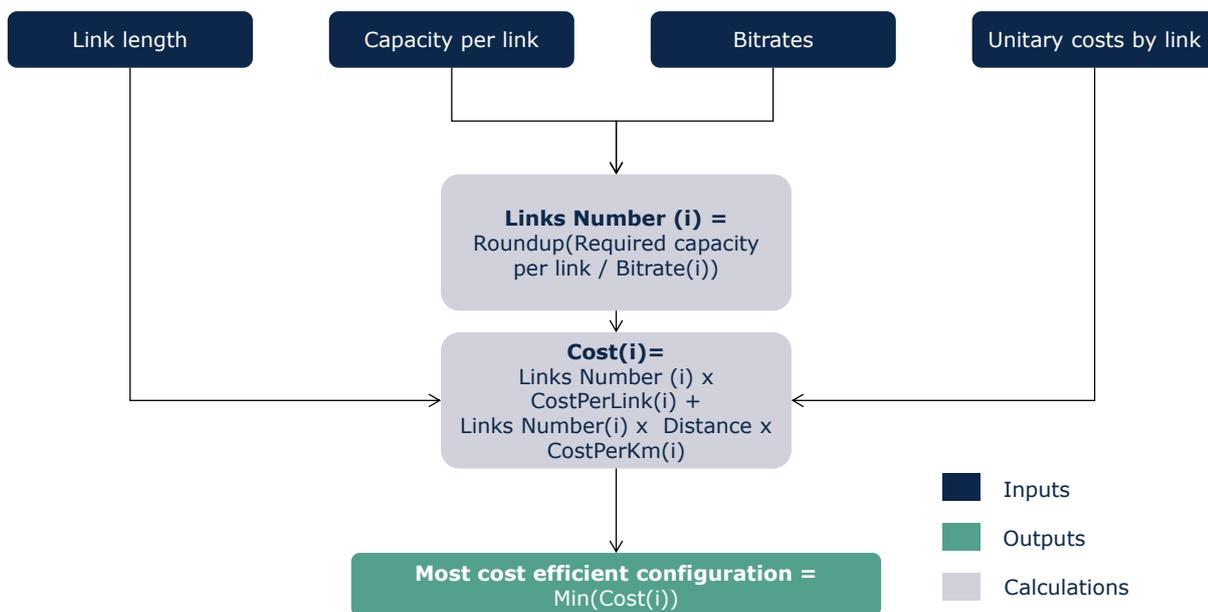


**Exhibit 6.29: Calculation of the optimum configuration of links. [Source: Axon Consulting]**

The cheapest configuration for each link is chosen. The procedure is then repeated for the entire list of links included in the model, until all links are covered.

### Step 2. Calculation of DWDM Regional Links

The calculations performed in this step are equivalent to those underlined in Step 1, except that the taken inputs correspond to DWDM Regional Links.

### Step 3. Calculation of DWDM Main Links

The calculations performed in this step are equivalent to those underlined in Step 1, except that the taken inputs correspond to the DWDM Main Links.

## 6.2.2 IP/MPLS network

The IP/MPLS network of the modelled operator is structured as shown in the following illustrative representation:
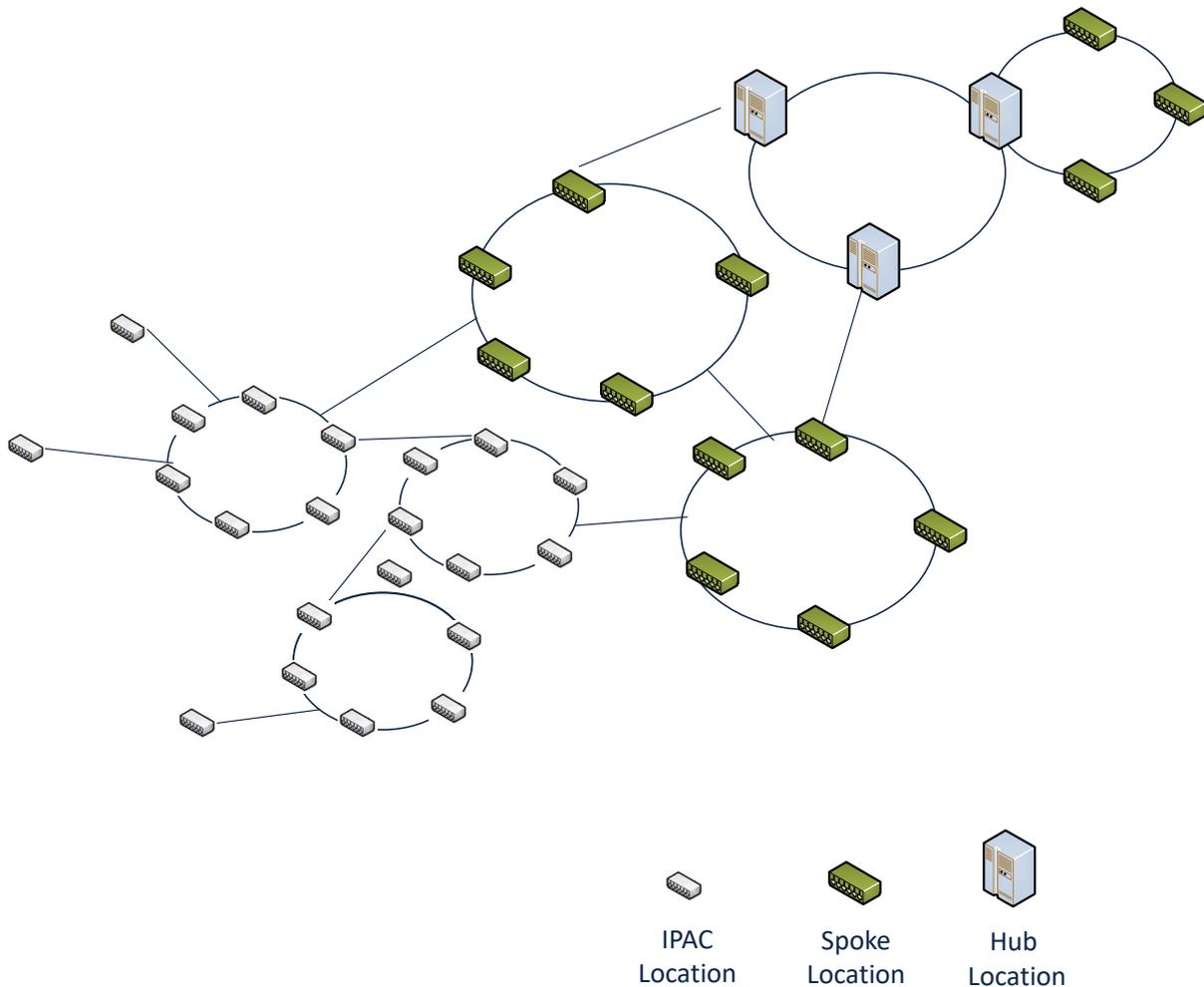


**Exhibit 6.30: Overview of the general architecture considered in the IP/MPLS network [Source: Axon Consulting]**

In light of the above structure, locations are divided in the following categories:

▶ *IPAC Location*

▶ *Spoke Location*

▶ *Hub Location*

The dimension of the transmission locations has been optimised taking into consideration the position of the operators' network elements. Specifically, information provided by operators have been taken to determine the different locations in the country.

The dimensioning of the locations selects the cheapest configuration available that is able to handle the location's traffic.

The percentage of traffic that will circulate through each location is introduced based on the percentage of active premises for which the associated traffic will need to circulate through that location.

### *Step 1. Calculation of IPAC Locations*

As a first step, the model calculates the number of equipment that would be required under each configuration, based on their bitrate. Knowing the number of equipment required, the model then calculates their associated costs, and selects the most cost-efficient alternative among those available, as shown in the illustration below:
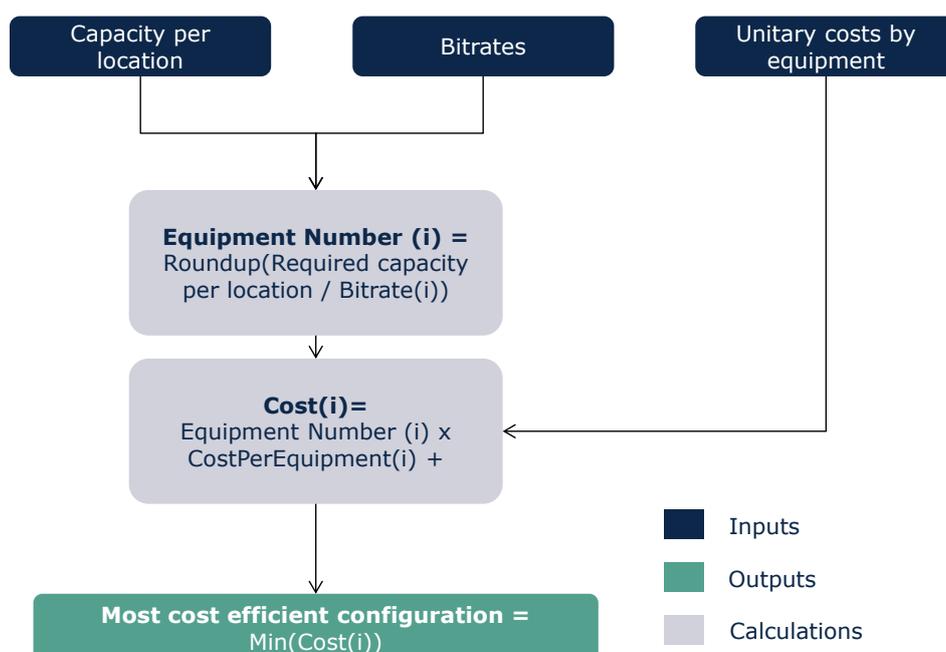


**Exhibit 6.31: Calculation of the optimum configuration [Source: Axon Consulting]**

The cheapest configuration for each location is chosen. The procedure is then repeated for entire list of locations included in the model, until all locations are covered.

### Step 2. Calculation of Spoke Locations

The calculations performed in this step are equivalent to those underlined in Step 1, except that the taken inputs correspond to Spoke Locations.

### Step 3. Calculation of Hub Locations

The calculations performed in this step are equivalent to those underlined in Step 1, except that the taken inputs correspond to the Hub Locations.

## 6.2.3 Other transmission elements

This section describes the approach followed for the dimensioning of other transmission elements, namely:

▶ Additional trenches for the transmission network

▶ ODFs for the transmission network

▶ Microwave links

▶ Other IP equipment

### Additional trenches for the transmission network

This step presents the calculation of the additional kilometres of trenches that are required in the transmission network.

At this stage, it is important to note that the kilometres of trenches shared between the access and the core networks have been allocated to both networks based on a 50%-50% split. The exhibit below illustrates the algorithm used to calculate these additional trenches that need to be deployed.
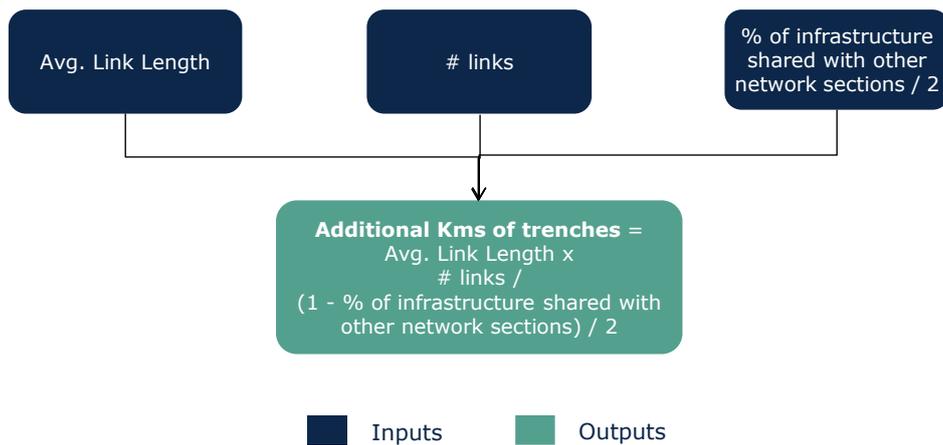
**Exhibit 6.32 Calculation of additional trenches to be deployed [Source: Axon Consulting]**

The same process is repeated for the three types of links:

▶ CWDM or DWDM Metro Links

▶ DWDM Regional Links

▶ DWDM Main Links

### *ODFs for the transmission network*

The exhibit below illustrates the algorithm used to calculate the number of ODFs for the transmission network.
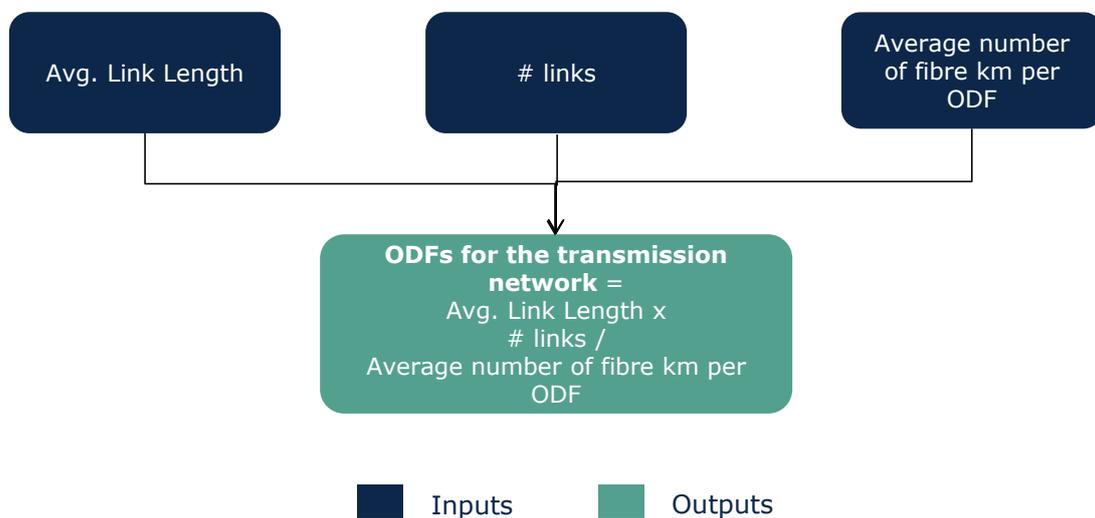


**Exhibit 6.33 Calculation of ODFs for the transmission network [Source: Axon Consulting]**

The same process is repeated for the three types of links:

▶ CWDM or DWDM Metro Links

▶ DWDM Regional Links

▶ DWDM Main Links

***Microwave links***

The approach for the dimensioning of Microwave links is equivalent to that followed for the IP/MPLS locations, described in section 6.2.2. above.

In particular, the dimensioning of the microwave links selects the cheapest configuration available that is able to handle the location's traffic.

***Other IP equipment***

The number of equipment of "IP switch device", "PE router device" and "VPN concentrator device" is calculated as the total IP traffic handled in the network divided by the average capacity of each of these types of devices.

# 6.3. Core Network Dimensioning (geotype independent)

The Core Network Dimensioning module is responsible for the dimensioning of the Core Equipment, dealing with the central network management. This process is performed at the end (block 2) of the worksheet '7A CALC DIM CORE´ of the Model.

The model considers an NGN core network, which represents the MEA of traditional fixed networks. In that context, NGN core network is able to provide all retail and wholesale services currently sold by operators. However, it is important to note that specific voice platforms, not being the results of voice services under the scope of this Model, have not been modelled. The following network elements have been modelled:

▶ **HSS (Home Subscriber Server)**: Responsible for storage of various kinds of subscriber-related data, including authentication credentials, details of services subscribed. The number of units has been limited by the nominal capacity in terms of subscribers:

$$HSS\ Number \geq \frac{Total\ Connections\ (Subs))}{Technical\ Constraint\ (Subs)}$$

▶ **BRAS (Broadband Remote Access Server)**: Responsible for aggregating user sessions from the access network to Internet. The number of units has been limited by the nominal capacity in terms of broadband users connected simultaneously:

$$BRAS\ Number \geq \frac{Total\ \text{Simulaneous}\ Connections\ (Subs))}{Technical\ Constraint\ (Subs)}$$

▶ **RADIUS (Remote Authentication Dial-In User Service):** Provides authentication and authorization remote services to handle the usage of a network resource by the users. The number of units has been limited by the nominal capacity in terms of broadband users connected simultaneously:

$$RADIUS\ Number \geq \frac{Total\ \text{Simulaneous}\ Connections\ (Subs))}{Technical\ Constraint\ (Subs)}$$

▶ **DNS (Domain Name System):** Responsible for translating domain names to numerical IP addresses. The number of units has been limited by the nominal capacity in terms of broadband users connected simultaneously:

$$DNS\ Number \geq \frac{Total\ \text{Simulaneous}\ Connections\ (Subs))}{Technical\ Constraint\ (Subs)}$$

▶ **VoD Server (Video On-demand Server):** Provides customized video contents under user requests. One VoD Server unit has been modelled provided that the number of core connections are not zero.

▶ **IPTV Platform:** Responsible for processing, modulating and coding the TV signal before its transmission. One IPTV Platform unit has been modelled provided that the number of IPTV connections is not zero.

# 7. CapEx & OpEx Costs Module

The purpose of the CapEx & OpEx Costs Module is to calculate the expenditures (CapEx and OpEx) associated with the required network resources coming from the Dimensioning Module. This section presents the steps to obtain these expenses, as illustrated in the following figure.

> **Step 1. Determination of unit costs of Resources and application of trends**

> **Step 2. Calculation of Resources acquisition**

> **Step 3. Calculation of annual CAPEX and OPEX**
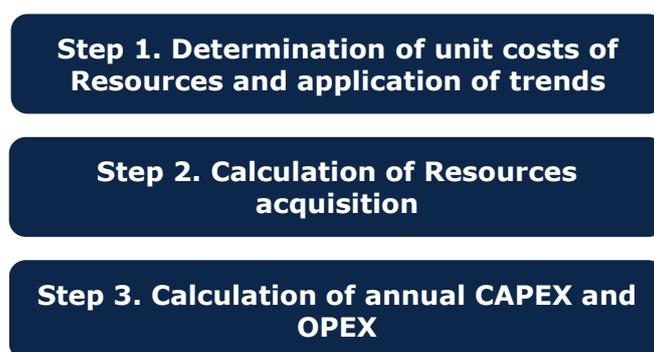
**Exhibit 7.1: Resources Costing [Source: Axon Consulting]**

The following sections explain each step in detail.

## 7.1. Step 1. Determination of Resources' Unit Costs and Cost Trends

For the definition of the unitary costs of the resources considered in the Model, two inputs are needed:

► **Unitary cost**: Separated in CAPEX and OPEX (for those resources where applicable) in the historic period. This information is introduced in the worksheet `1E INP UNITARY COSTS´.

► **Cost trends**: For each resource, a cost trend can be introduced, outlining the expected evolution of its prices (both CapEx and OpEx separately) in the future period. This information is introduced in the worksheet `1F INP COST TRENDS´.

Once historic unit costs and cost trends have been introduced, the Model will apply the trend where unit cost have not been introduced (i.e. usually in future years). The formula used for the application of cost trends is the following.

$$Unit\ Cost\ (year) = Unit\ Cost\ (year - 1) * \big(1 + Trend\ (year)\big)$$

In addition to the above, in the case of the annual unitary OPEX for copper assets, a mechanism has been implemented in the model that allows saving operational costs in copper assets in the future. In this sense, it is logical to assume that, since customers are migrating from copper towards fibre services, the operator will not dedicate the same efforts of operational and maintenance expenditures to copper assets in the future. Indeed, these operational expenditures are expected to decrease in line with the copper demand. For this purpose, the model is assuming that the unitary OpEx of the copper resources evolves as follows:

$$Unitary\ OpEx\ adjusted\ (year\ n) = Unitary\ OpEx\ (year\ n) \cdot \frac{lines\ copper\ (year\ n)}{lines\ copper\ (year\ of\ reference)}$$

The year of reference assumed is 2018. Resources for which this adjustment is introduced are marked with "Yes" in column "To apply cost reduction for OpEx over the years?" of the worksheet "0B PAR RESOURCES".

## 7.2. Step 2. Calculation of Resources Acquisition

In Step 2, the calculation of Capital Expenditures (CAPEX) that is needed to obtain new acquisitions is produced for each year. The following algorithm is used:
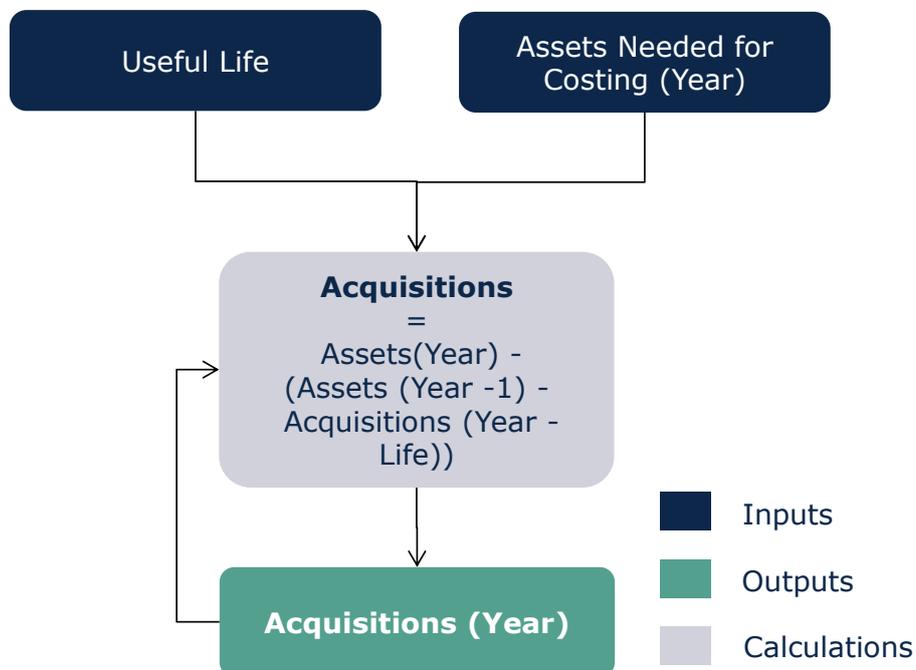


**Exhibit 7.2: Algorithm for the Calculation of New Acquisitions [Source: Axon Consulting]**

New acquisitions can be driven by two factors, network deployment or equipment's replacement, as follows:

▶ **Network deployment:** The roll-out of new or existing technologies, or the acquisition of new equipment for increasing the capacity, will be determined by additional network requirements to meet the demand.

▶ **Equipment replacement:** Once the equipment's useful life is expired, and when this resource is still necessary due to network requirements, the resource is replaced. In some cases, when the equipment is not required anymore, the equipment is just dismantled but not replaced.

# 7.3. Step 3. Calculation of Annual CAPEX and OPEX

Once the unit cost and the new acquisitions for each resource and year are determined, a P*Q system will be used to obtain the expenditures. The calculation of annual CAPEX (before annualized) and OPEX follows the algorithm:
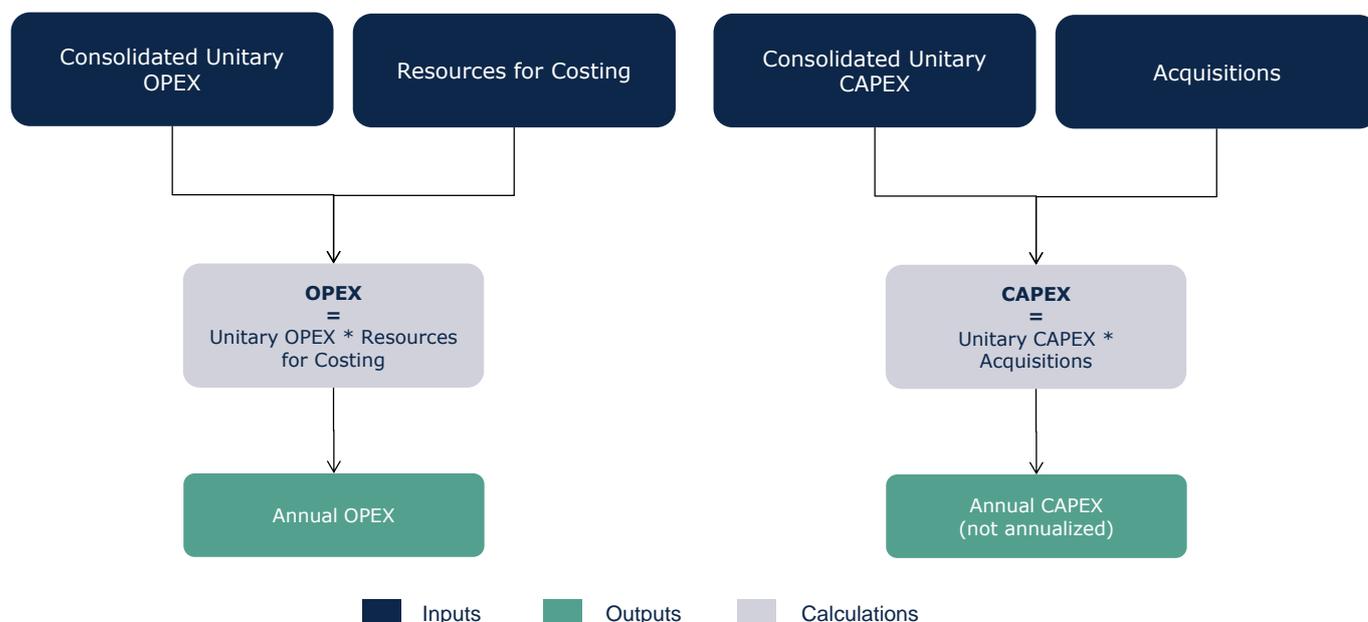


**Exhibit 7.3: Algorithm for the Calculation of the Annual CAPEX and OPEX [Source: Axon Consulting]**

Additionally, once the CAPEX is calculated, and before its annualization, two adjustments need to be introduced:

▶ Removal of investments covered by the funds received under the ONP[10] program. Funds received as part of the National Aid Programmes need to be discounted from the

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[10] National framework programme for the Development of Broadband Infrastructure in Areas Lacking Sufficient Commercial Interest for Investments

total investments required by the reference operator for the roll-out of fibre networks, given that these costs should not be allocated to the wholesale services. Amounts related to these funds are included as input at the end of worksheet `1E INP UNITARY COSTS´ of the model.

▶ Consideration of fully depreciated assets. It is important to note that, in order to align the model with the provisions of the EC's Recommendation 2013/466/EU, it is essential to identify the costs from fully depreciated assets that have already been recovered by the modelled operator. These refer to the assets that no longer generate any depreciation costs but are still being used by the operator. This is likely to be the result of a misalignment between the useful life considered financially for an asset and its technical useful life. These fully depreciated assets should not be considered to avoid an overvaluation of the Regulatory Asset Base.

For the practical implementation of this directive within the model, a percentage of relevant assets which are still generating costs to the operator has been considered within the model, based on the SMP operator's audited Fixed Asset Register (FAR). This input is included in worksheet '2D INP RESOURCES LIVES' of the model and it is applied over the investments required. Further details about the calculation of the input percentages are provided in the Consultation Document.

# 8. Depreciation Module

The Depreciation Module aims at calculating several alternative annualisation methods to distribute CAPEX over the years (annualisation). This section presents the following depreciation methods:

▶ Tilted annuities

▶ Economic depreciation

The chosen depreciation mechanism might have a relevant influence in the results of the Model.

### 8.1.1 Tilted annuities

The tilted annuities approach aims to adapt the profile of cost recovery with the objective of recognising 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 recognised for both market participants, not taking into account the time when they entered the market.

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

$$d_i = GRC_i \cdot \frac{WACC - Price\ trend}{1 - \left(\frac{1 + Price\ trend}{1 + WACC}\right)^{UL}}$$

Where:

▶ GRC is the Gross Replacement Cost associated to the asset

▶ di is the annualised costs at year i (within the useful life)

▶ WACC is the Weighted Average Cost of Capital

▶ Price trend is the rate of price change associated to the asset

▶ UL is the useful life of the asset

## 8.1.2 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

▶ $\omega$ 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.

# 9. Cost allocation to 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 LRIC+ standard.

## 9.1. Incremental and common costs calculation

The incremental cost associated to 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 are 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 LRIC+ model (which calculates the cost according to demand and coverage), $vi$ 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 '0D PAR OTHER') a unique increment has been defined grouping all services. Services are then assigned to this increment in Sheet '0A PAR SERVICES'.

Once incremental costs are calculated for this increment as described previously, common costs by 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:

$$COMMON\ COST = TOTAL\ COSTS\ (Fully\ Allocated\ Costs) - INCREMENTAL\ COST(Without\ demand)$$

In the model, resources' incremental costs are calculated in sheet '9C CALC RES COST CONSOL' while common costs are shown in sheet '11A CALC RES COMMON COST'.

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

## 9.2. Resources' costs imputation to services

Incremental costs are allocated to services using Routing Factors. This methodology allocates costs to products based on the use made 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 cost imputation process is done in two main steps (see the Figure below):

▶ Step 1. Combination of Routing Factors and Services' Traffic

▶ Step 2. Cost allocation to services based on such combination
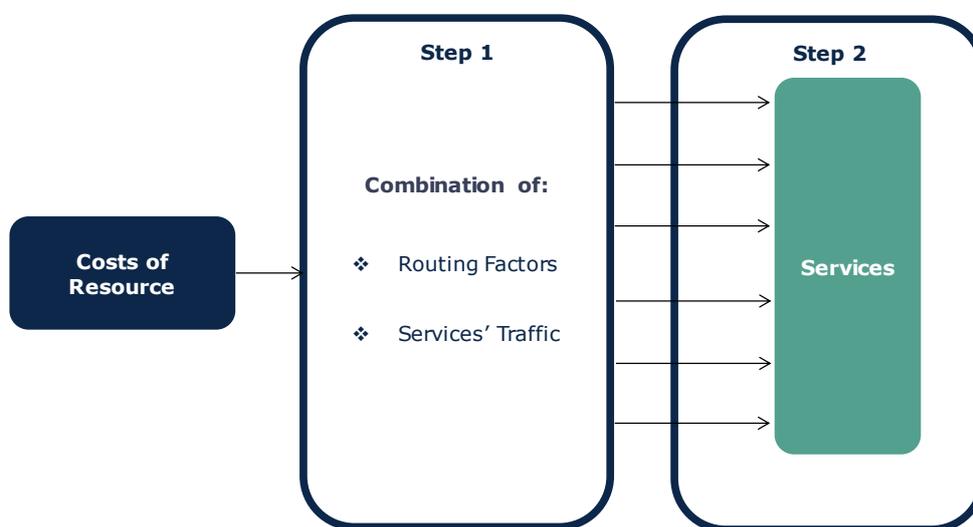


**Exhibit 9.1: Cost Imputation Process using Routing Factors [Source: Axon Consulting]**

Once incremental costs have been allocated, the allocation of common costs is based on an Effective Capacity approach. This methodology allocates common costs also through the Routing Factors, following the same philosophy as the incremental costs.

Finally, once network costs have been allocated, general and administrative expenditures (G&A) and wholesale specific costs are allocated to all services following a separate mark-up on top of services costs.

More details about Steps 1 and 2 are provided in following paragraphs.

## 9.2.1 Step 1: Combination of Routing Factors and Services' Traffic

The methodology used to allocate resources' costs to services is based on the idea that the cost of a resource has to be imputed to services proportionally to the amount of traffic generated by the service itself, and to a "factor of use", the Routing Factor. 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.

Below there is an illustrative excerpt showing some examples of Routing Factor associations between Services and Resources.

| EQUIVALENT EQUIPMENT (Group of resources) | Service CATEGORY | Service SUBCATEGORY | Service SEGMENT | Service DESCRIPTION | Routing Factor |
|---|---|---|---|---|---|
| Fibre building installation | Access | FTTH | Retail | Access | 1,00 |
| Fibre building installation | Access | FTTB | Retail | Access | - |
| Fibre building installation | Access | FTTDP | Retail | Access | - |
| Fibre building installation | Access | FTTH - Unbundled at DP level (PTP) | Wholesale - Local Access Lines - Market 3A | Access | 1,00 |
| Fibre building installation | Access | FTTH - Unbundled at ODF level (PTP) | Wholesale - Local Access Lines - Market 3A | Access | 1,00 |
| Fibre building installation | Access | FTTH | Wholesale - Central Access Lines - Market 3B | Access | 1,00 |
| Fibre building installation | Access | FTTB | Wholesale - Central Access Lines - Market 3B | Access | - |
| Fibre building installation | Access | FTTDP | Wholesale - Central Access Lines - Market 3B | Access | - |

**Exhibit 9.2: Illustrative extract of Routing Factor Correlation to Services and Resources (Sheet '3C MAP ROUTING FACTORS') [Source: Axon Consulting]**

## 9.2.2 Step 2: Cost Allocation to Services

Once the weight of a single service in relation to each different asset has been established, it is possible to distribute all costs to all services.

The basic relation is the following:

$$ServiceCost(i, year) = \sum_n \frac{Asset(n, year) \cdot Traffic(i, year) \cdot RF(i,n)}{\sum_i Traffic(i, year) \cdot RF(i,n)}$$

Where:

▶ ServiceCost (i, year) is the cost of service i in an established year

▶ Asset (n,year) is the cost of resource n in that year

▶ Traffic (i, year) is the traffic of the service i in the selected year

▶ RF (i,n) is the Routing Factor that relates the resource n with the service i

The allocation of resources' cost to services is presented in the sheet `10B CALC SERV INCR COST´ and , where the formula used allows the implementation of steps described under this section 9.2.

# Services' descriptions

This annex contains a description of the services that have been included in the cost model.

► **Fibre Access services:** These services provide access to the customers by means of fibre networks:

- **'Access.FTTH.Retail.Access':** Provision of a FTTH (Fibre-To-The-Home) line to an end customer. Its unit cost is comprised of the cost of the access network, from the customer premise up to the access nodes (until the Optical Distribution Frame, including the cost of the ODF and excluding the cost of the OLT). Please note that the conveyance of the traffic generated by the subscriber is included in other services such as broadband or TV services.

- **'Access.FTTB.Retail.Access':** Provision of a FTTB (Fibre-To-The-Building) line to an end customer. Its unit cost is comprised of the cost of the access network, from the customer premise up to the access nodes (until the ODF, including the cost of the ODF and excluding the cost of the OLT). Please note that the conveyance of the traffic generated by the subscriber is included in other services such as broadband or TV services.

- **'Access.FTTDP.Retail.Access':** Provision of a FTTDP (Fibre to the Distribution Point) line to an end customer. Its unit cost is comprised of the cost of the access network, from the customer premise up to the access nodes (until the ODF, including the cost of the ODF and excluding the cost of the OLT). Please note that the conveyance of the traffic generated by the subscriber is included in other services such as broadband or TV services.

- **'Access.FTTH - Unbundled at DN level (PTP) .Wholesale - Local Access Lines - Market 3A.Access':** Wholesale access service offered to alternative operators which consists in providing the unbundled access to the fibre network at the location of the Distribution Node (DN). Its unit cost is comprised of the cost of the access network, from the customer premise up to the access nodes (until the DN, including the cost of the DN).

- **'Access.FTTH - Unbundled at ODF level (PTP).Wholesale - Local Access Lines - Market 3A.Access':** Wholesale access service offered to alternative operators which consists in providing the unbundled access to the fibre network at the location of the ODF. Its unit cost is comprised of the cost of the access network, from the customer premise up to the access nodes (until the ODF, including the cost of the ODF). Please note that this service is not currently provided by the SMP operator and, thus, it refers to a hypothetical service. Additionally, please note that the model's user needs to the select the option "Alternative design (Splitter only

located in the ODF level)" for the scenario "Dimensioning rules for fibre networks" located in the CONTROL panel, in order to produce a cost for this service.

- **'Access.FTTH.Wholesale - Central Access Lines - Market 3B.Access':** Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **'Access.FTTB.Wholesale - Central Access Lines - Market 3B.Access':** Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **'Access.FTTDP.Wholesale - Central Access Lines - Market 3B.Access':** Wholesale service which is in terms of network costs equivalent to its analogous retail service.

▶ **Copper Access services:** These services provide access to the customers by means of copper networks.

- **'Access.Copper.Retail.Access':** Provision of a copper line to an end customer. Its unit cost is comprised of the cost of the access network, from the customer premise up to the access nodes (until the Main Distribution Frame, including the cost of the MDF and excluding the cost of the MSAN/DSLAM). Please note that the conveyance of the traffic generated by the subscriber is included in other services such as broadband or TV services.

- **'Access.FTTC.Retail.Access':** Provision of a FTTC (Fibre-To-The-Cabinet) line to an end customer. Its unit cost is comprised of the cost of the access network, from the customer premise up to the access nodes (until the Main Distribution Frame, including the cost of the MDF and excluding the cost of the MSAN/DSLAM). Please note that the conveyance of the traffic generated by the subscriber is included in other services such as broadband or TV services.

- **'Access.LLU.Wholesale - Local Access Lines - Market 3A.Access':** Wholesale service offered to alternative operators which consists in providing the unbundled access to the local loop. Its unit cost is comprised of the cost of the access network, from the customer premise up to the access nodes (until the Main Distribution Frame, including the cost of the MDF and excluding the cost of the MSAN/DSLAM).

- **'Access.Copper.Wholesale - Central Access Lines - Market 3B.Access':** Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **'Access.FTTC.Wholesale - Central Access Lines - Market 3B.Access':** Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **'Access.WLR.Wholesale - Central Access Lines - Market 3B.Access':** Wholesale Line Rental (WLR) service offered to alternative operators. This service is, in terms of network costs, equivalent to the 'Access.Copper.Wholesale - Central Access Lines - Market 3B.Access'. However, in this case, the alternative operator is only offering voice services to its end subscriber (without broadband services).

▶ **Broadband services:** Services that include the costs of providing broadband services. These services are disaggregated between services per line and services per Mbps (it is worth noting that both types of services need to be combined in order to compound the cost of an end customer), as follows:

- **Services per line**: These services gather the cost of the DSLAM/MSAN (in the case of copper services) or the OLT (in the case of fibre services), as follows:

    - **Broadband.Fibre.Retail.Broadband**. This service gathers the cost of the OLT and related OLT card/port associated to an end customer.

    - **Broadband.Fibre.Wholesale.Broadband**. Wholesale service which is in terms of network costs equivalent to its analogous retail service.

    - **Broadband.Copper - ADSL.Retail.Broadband**. This service gathers the cost of the MSAN/DSLAM and related ADSL card/port associated to an end customer.

    - **Broadband.Copper - VDSL.Retail.Broadband**. This service gathers the cost of the MSAN/DSLAM and related VDSL card/port associated to an end customer.

    - **Broadband.Copper - ADSL.Wholesale.Broadband**. Wholesale service which is in terms of network costs equivalent to its analogous retail service.

    - **Broadband.Copper - VDSL.Wholesale.Broadband**. Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **Services per Mbps**: These services gather the cost of the remaining transmission and applicable core equipment necessary for the conveyance of traffic:

    - **Broadband.Fibre/Copper.Retail.Broadband.** It includes the costs associated to the transmission of the broadband traffic of a retail customer from the DSLAM/OLT (excluding the cost of the DSLAM/OLT) up to the Internet[11].

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[11] It is worth noting that the cost of the international connectivity to Internet is not included.

- **Broadband.FTTC - Additional .Retail.Broadband.** It includes the additional cost (to be added to the previous service) associated to the transmission of broadband traffic of a FTTC retail customer from the cabinet location up to the corresponding node of the aggregation network.

- **Broadband.Fibre/Copper.Wholesale services.** They include the costs associated to the transmission of the broadband traffic associated to a Requesting Party's customer from the access node (DSLAM/OLT, excluding the cost of the DSLAM/OLT) up to the point where the traffic is interconnected to the Requesting Party. In this sense, five different services are included in the model depending on the point where the traffic is interconnected:

    - Wholesale - DSLAM/OLT level[12]

    - Wholesale - Ethernet level

    - Wholesale – Ethernet level at Ethernet switch

    - Wholesale - IP level - Regional

    - Wholesale - IP level – National

- **Broadband.FTTC - Additional .Wholesale.Broadband.** Wholesale service which is in terms of network costs equivalent to its analogous retail service.

▶ **Virtual channels:**

- **'Virtual Channel.SD IPTV.Wholesale.Virtual Channel':** Wholesale service which comprises the cost of conveying a specific SD IPTV channel to the Requesting Party's customers. This service provides the unitary cost per channel. Additionally, the model is also able to produce the equivalent unitary cost per user, shown as a KPI "Virtual Channel per user.SD IPTV.Wholesale.Virtual Channel per user" at the end of the worksheet "12B OUT SERV LRIC+ UNIT COST".

- **'Virtual Channel.SD/HD IPTV.Wholesale.Virtual Channel':** Wholesale service which comprises the cost of conveying a specific SD/HD IPTV channel to the Requesting Party's customers. This service provides the unitary cost per channel. Additionally, the model is also able to produce the equivalent unitary cost per user, shown as a KPI "Virtual Channel per user. SD/HD IPTV.Wholesale.Virtual Channel per user" at the end of the worksheet "12B OUT SERV LRIC+ UNIT COST".

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[12] This service is equal to zero as no additional traffic per Mbps is incurred at this point of interconnection.

- **'Virtual Channel.VoIP':** Wholesale service which comprises the cost of conveying a specific VoIP channel of the Requesting Party's customer. Three different services are included in the model depending on the point where the traffic is interconnected:

    - Wholesale - Ethernet level

    - Wholesale - IP level - Regional

    - Wholesale - IP level - National

- **'Virtual Channel.Controlling user equipment.Wholesale.Virtual Channel':** Wholesale service which provides a special virtual channel to control the user equipment and allows the seeker operator to remote monitoring and management of user equipment. Three different services are included in the model depending on the level of interconnection:

    - Wholesale – Ethernet level

    - Wholesale – Regional

    - Wholesale - National

▶ **TV Services:** These services include costs of conveying TV traffic for retail customers.

- **'IPTV - Over the set top box.IPTV.Retail.SD channels'**. This service comprises the cost of conveying a SD IPTV channel to the end customers (provided over the set top box). This service provides the unitary cost per channel.

- **'IPTV - Over the set top box.IPTV.Retail.HD channels'**. This service comprises the cost of conveying a HD IPTV channel to the end customers (provided over the set top box). This service provides the unitary cost per channel.

    Additionally, for the two services above, the model is also able to produce the equivalent unitary cost per user, shown as a KPI "IPTV - Over the set top box.IPTV.Retail.IPTV" at the end of the worksheet "12B OUT SERV LRIC+ UNIT COST".

- **'VoD - Over the set top box.VoD - Mbps.Retail.VoD'**. This service represents the cost of transmitting 1 Mbps of video on demand through the network. The cost is associated to the transmission of video on demand traffic and its usage of the platforms in the transmission/core networks. Additionally, the model is also able to produce the equivalent unitary cost per user, shown as a KPI "VoD - Over the set top box.VoD.Retail.VoD" at the end of the worksheet "12B OUT SERV LRIC+ UNIT COST".

▶ **High-Quality Services:**

- **'High-Quality Services.Transport IP / MPLS .Retail.Trunk segment':** High-Quality service provided through the IP/MPLS network. This service comprises the cost of conveying 1 Mbps through the trunk segment, in particular, between two IP Spoke locations.

- **'High-Quality Services.Ethernet line L2 P2P.Retail.Trunk segment':** High-Quality service provided with a Point-to-Point connection through the IP/MPLS network. This service comprises the cost of conveying 1 Mbps through the trunk segment, in particular, between two IPAC locations.

- **'High-Quality Services.Ethernet VPLS - E-LAN - MP2MP.Retail.Trunk segment':** High-Quality service provided with a MultiPoint-to-MultiPoint connection through the IP/MPLS network. This service comprises the cost of conveying 1 Mbps through the trunk segment, in particular, between two IPAC locations.

- **'High-Quality Services.DWDM lines.Retail.Trunk segment':** High-Quality service provided through the DWDM network. This service comprises the cost of conveying 1 Mbps through the trunk segment.

- **'High-Quality Services.Transport IP / MPLS .Wholesale.Trunk segment'**: Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **'High-Quality Services.Ethernet line L2 P2P.Wholesale.Trunk segment'**: Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **'High-Quality Services.Ethernet VPLS - E-LAN - MP2MP.Wholesale.Trunk segment'**: Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **'High-Quality Services.Mobile backhauling.Wholesale.Trunk segment'**: Wholesale high-quality service provided for connecting the base stations of a Requesting mobile operator. This service comprises the cost of conveying 1 Mbps through the trunk segment.

- **'High-Quality Services.DWDM lines.Wholesale.Trunk segment'**: Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **'High-Quality Services.Terminating segment.Retail.Terminating segment':** Terminating segment of a high-quality product. This service comprises the cost per segment of connecting the customer location with the aggregation network of the SMP operator, as well as the CPE (Customer Premise Equipment).

- **'High-Quality Services.Terminating segment.Wholesale.Terminating segment'.** Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **High-Quality Services.Terminating segment SHDSL.Retail.Terminating segment SHDSL.** This service includes the cost of the SHDSL card and MSAN/DSLAM necessary for the provision of a SHDSL terminating high-quality product as well as the CPE SHDSL modem. Please note that, to reflect the cost of the segment connecting the customer location with the operator's node, the cost of the corresponding copper access service (see these services in previous paragraphs) should be added on top to this service.

- **High-Quality Services.Terminating segment SHDSL.Wholesale.Terminating segment SHDSL.** Wholesale service which is in terms of network costs equivalent to its analogous retail service.

- **'High-Quality Services. Terminating segment (up to 4 Mbps).Retail.Terminating segment'.** Terminating segment of a high-quality product with speed up to 4Mbps. This service comprises the cost of connecting the customer location with the aggregation network of the SMP operator, as well as the CPE (Customer Premise Equipment).

- **'High-Quality Services. Terminating segment (up to 4 Mbps).Wholesale.Terminating segment'.** Wholesale service which is in terms of network costs equivalent to its analogous retail service.

# Additional functionalities of the model

The model includes a set of additional functionalities aiming at calculating the costs of additional services as well as the obtention of some KPIs. These additions are listed below and explained in detail in the following sections:

## Annex B.

▶ Dark Fibre Module

### *Dark Fibre Module*

The Dark Fibre module aims at calculating the cost incurred by the operator when offering the Dark Fibre service. The result is calculated as the cost per meter of strand of fibre per month. This cost has been divided in two different network sections which are described in detail below:

▶ Transmission Network

Unitary costs are finally calculated on a monthly basis for each year as the total cost of the relevant resources divided by the total length of fibre cables in the transmission network, by the average number of strands per fibre cable and by the average % of strands in fibre cables actually occupied:
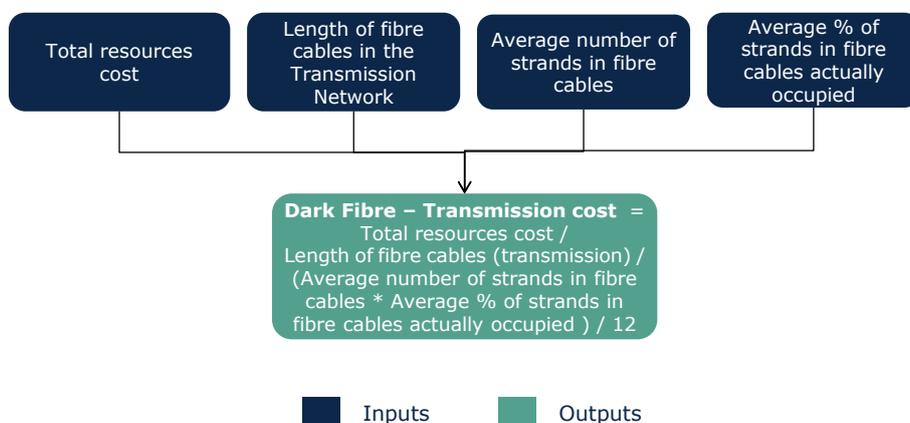


**Exhibit 6. Algorithm for calculating the monthly cost of the Dark Fibre service for the Transmission Network [Source: Axon Consulting]**

▶ Access Network

### *Transmission Network*

In this section, the cost of the dark fibre in the transmission network of the operator is calculated. This process is performed in the additional worksheet of the Model named "ADD. MOD. DARK FIBRE".

In order to be able to compute this cost, a set of additional inputs are included in the model regarding the fibre cables characteristics:

| | |
|---|---|
| **Average number of strands in fibre cables** | - |
| **Average % of strands in fibre cables actually occupied** | - |
| **Mark-up for wholesale specific costs (over OpEx)** | - |

**Exhibit 57. Example of the inputs for modelling the Dark Fibre services [Source: Axon Consulting]**

Once these input parameters are set, the specific resources employed for the provision of the dark fibre service are selected, and the related CAPEX and OPEX are extracted from the CapEx & OpEx Costs Modules of the model (these are the model's modules used for the calculation of the rest of modelled services).

**CAPEX**

| Services | Units | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transmission - Sec 1.Fibre.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Transmission - Sec 1.Trenches.km | HRK | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - |
| Transmission - Sec 2.Fibre.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Transmission - Sec 2.Trenches.km | HRK | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - |
| Transmission - Sec 3.Fibre.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Transmission - Sec 3.Trenches.km | HRK | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - |

**Exhibit 58. Example of the resources included in the Dark Fibre service [Source: Axon Consulting]**

Furthermore, the G&A and the Wholesale Specific costs are computed as a mark-up over network costs.

Once all the costs are computed, the total units of each relevant resource needed for the unitary cost calculation are extracted from the worksheet "8A CONSOL RES":

**RESOURCES UNITS**

| Services | Units | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transmission - Sec 1.Fibre.length | km | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - |
| Transmission - Sec 2.Fibre.length | km | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - |
| Transmission - Sec 3.Fibre.length | km | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - |

**Exhibit 59. Example of the resources' units used for calculating the unit cost of the Dark Fibre service in the Transmission Network [Source: Axon Consulting]**

Unitary costs are finally calculated on a monthly basis for each year as the total cost of the relevant resources divided by the total length of fibre cables in the transmission network, by the average number of strands per fibre cable and by the average % of strands in fibre cables actually occupied:
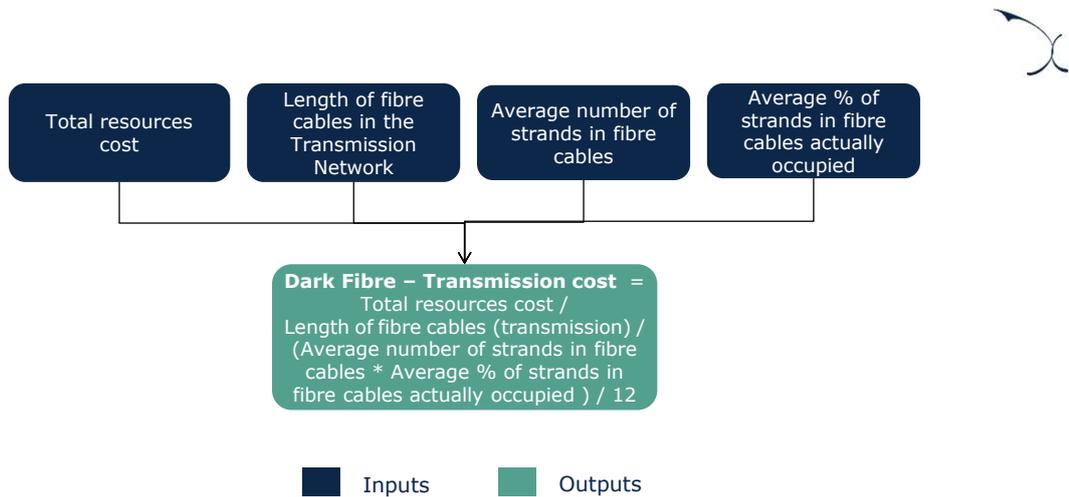
**Exhibit 6. Algorithm for calculating the monthly cost of the Dark Fibre service for the Transmission Network [Source: Axon Consulting]**

*Access Network*

In this section, the cost of the dark fibre in the access network of the operator is calculated. This process is also performed in the additional worksheet of the Model named "ADD. MOD. DARK FIBRE".

The calculation process is analogous to the procedure detailed in the Transmission Network section. However, the resources producing cost and resources units are different between both networks (access vs transmission networks):

CAPEX

| Services | Units | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Access Fibre Cable.1 strand - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.2 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.4 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.8 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.12 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.24 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.48 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.96 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.144 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.216 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.288 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.432 strands - Aerial.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.1 strand - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.2 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.4 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.8 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.12 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.24 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.48 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.96 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.144 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.216 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.288 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre Cable.432 strands - Underground.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre .Fibre joint - 96 splices.# of joints | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre .Fibre joint - 288 splices.# of joints | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Access Fibre .Fibre joint - 576 splices.# of joints | HRK | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - |
| Fibre infrastructure.Trench urban - with ducting.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Fibre infrastructure.Trench suburban - with ducting.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Fibre infrastructure.Trench rural - with ducting.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Fibre infrastructure.Trench urban - without ducting.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Fibre infrastructure.Trench suburban - without ducting.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Fibre infrastructure.Trench rural - without ducting.length | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Fibre infrastructure.Manhole.# of manholes | HRK | - | - | - | - | - | - | - | - | - | - | - |
| Fibre infrastructure.Poles.# of poles | HRK | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - |

**Exhibit 61. Example of the resources producing costs in the Dark Fibre service of the Access Network [Source: Axon Consulting]**

RESOURCES UNITS

| Services | Units | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Access Fibre.Occupied Fibre Strands (KPI, no cost attributable).length | km | - | - | - | - | - | - | - | - | - | - | - |

**Exhibit 62. Example of the resources' units in the Dark Fibre service of the Access Network [Source: Axon Consulting]**

Finally, the unitary cost is computed as a price per meter of strand of fibre in the Access Network following the equation below.
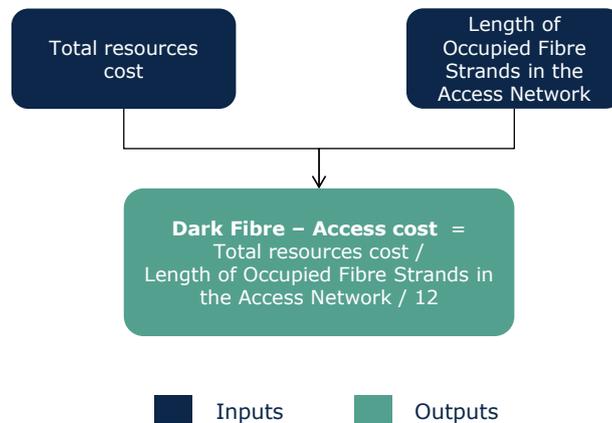


**Exhibit 63. Algorithm for calculating the monthly cost of the Dark Fibre service for the Access Network [Source: Axon Consulting]**

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