



Cost model of Ethernet transport

Descriptive manual

June 2022



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1. Introduction

This document 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 Ethernet transport ('the Model') commissioned by the Belgian Institute for Postal Services and Telecommunications (hereinafter, the BIPT) to Axon Partners Group (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 have already been discussed with IBPT 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)
Dimensioning method	Bottom-up approach.
Operator Type	Hypothetical national operator rolling-out a modern efficient network, sharing characteristics with Proximus
Assets valuation method	Current Cost Accounting (CCA)
Depreciation method	Economic Depreciation
Allocation of common network costs	Effective Capacity approach, while an EPMU approach is employed for the allocation of G&A and IT common costs
Network Topology	Scorched Node approach, using the existing locations of operators' network nodes



Methodological issue	Approach adopted
Transmission Technologies	Fibre Links (Ethernet with/without WDM) for layer 2 and being routed by means of the IP-MPLS solution on layer 3
Core Technologies	NGN Core Network, based on all-IP networks
Time horizon	2018-2027
Services	Retail and wholesale services that make use of the transmission and core networks including broadband, voice, IPTV, connectivity services, etc.
Increments	A unique increment is employed for all services
Costs to be considered	Network CapEx (Depreciation and Cost of Capital), Network OpEx and Overheads (G&A and IT costs)

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

1.2. Structure of the document

The remaining sections of this document describe:

- ▶ The modelling approach,
- ▶ 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 example Mbps) facilitating the dimensioning of network resources.
- ▶ **Geotypes definition**, presents the treatment performed to the data about network nodes located at local level 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 demand 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 Economic Depreciation method to distribute CAPEX and OPEX 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.

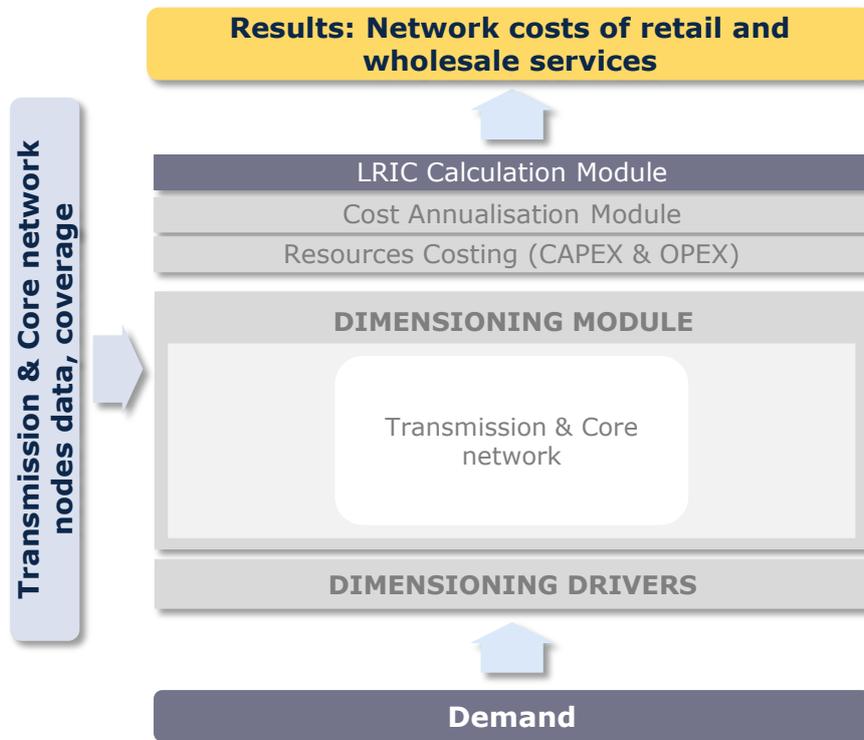


Exhibit 2.1: Structure of the model [Source: Axon Consulting]

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

- ▶ **Dimensioning drivers:** Converting 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, data about the transmission and core network nodes is introduced in the dimensioning module to take into consideration the relevant characteristics of the network.

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



- ▶ **Annualisation module:** Allocating CapEx and OpEx resources costs over time following the methodology defined. That is, employing the economic depreciation method.
- ▶ **LRIC costs calculation module:** Obtaining incremental costs 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:

- ▶ **Demand (1A INP DEMAND):** the demand, either expressed as traffic or as subscribers, is the main input to the model, and it represents the volume that must be supported by the network to be dimensioned. The demand is included in the model disaggregated based on the list of services defined in sheet "0A PAR SERVICES".
- ▶ **Unitary costs (1B INP UNITARY COSTS and 1C INP COST TRENDS):** each resource dimensioned in the model is assigned to a unitary cost, differentiating between CapEx and OpEx costs. Such unitary costs (CapEx and OpEx) are defined for historical years with an absolute value, and for projected years, based on a Year-on-Year price trend.
- ▶ **G&A and IT costs (1D G&A AND IT COSTS):** these overheads are introduced in the model as mark-ups (%), which are applied over the service cost.
- ▶ **Network dimensioning parameters and equipment capacity (2A INP NW):** dimensioning algorithms require information about the characteristics of the network equipment in terms of capacity. In addition, traffic statistics or parameters are also relevant for the network design (e.g., peak consumption per user, IPTV channel throughput, etc.).
- ▶ **Transmission & Core network nodes characterization (2B INP NW CHARACT):** the dimensioning of the network requires to take into consideration specific information about the transmission & core network (e.g., node locations, connections between them, etc.). In the case of nodes located at local level ("Regional nodes"), this information is aggregated by means of geotypes. Geotypes aggregation is produced by applying the methodology described in section 5 of this document.
- ▶ **Resources lives (2C INP RESOURCES LIVES):** the resources lives, which are assigned to the resources dimensioned in the model, are necessary for the annualization of the resources' costs.



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:

- ▶ The concept of dimensioning drivers
- ▶ Mapping services to drivers
- ▶ Conversion Factors from Services to Drivers

4.1. The concept of dimensioning drivers

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 demand requirements:

- ▶ Number of connections for the dimensioning of the network
- ▶ Mbps for transmission through the core network (including for instance broadband and IPTV multicast services).

The following list contains the drivers used in the BULRIC model:

Variable
DRIV.COPPER.Connections.Total Active connection
DRIV.FIBRE.Connections.Total Active connection
DRIV.DATA CONNECTIVITY.Connections.Total Active connection
DRIV.COPPER - LOCAL.Traffic.Data traffic
DRIV.FIBRE - LOCAL.Traffic.Data traffic
DRIV.DATA CONNECTIVITY - LOCAL.Traffic.Data traffic
DRIV.IPTV - LOCAL.Traffic.Data traffic
DRIV.VoD - LOCAL.Traffic.Data traffic
DRIV.VOICE - LOCAL.Traffic.Voice traffic
DRIV.COPPER - REGIONAL.Traffic.Data traffic
DRIV.FIBRE - REGIONAL.Traffic.Data traffic
DRIV.DATA CONNECTIVITY - REGIONAL.Traffic.Data traffic
DRIV.IPTV - REGIONAL.Traffic.Data traffic



Variable
DRIV.VoD - REGIONAL.Traffic.Data traffic
DRIV.VOICE - REGIONAL.Traffic.Voice traffic
DRIV.COPPER - NATIONAL.Traffic.Data traffic
DRIV.FIBRE - NATIONAL.Traffic.Data traffic
DRIV.DATA CONNECTIVITY - NATIONAL.Traffic.Data traffic
DRIV.IPTV - NATIONAL.Traffic.Data traffic
DRIV.VoD - NATIONAL.Traffic.Data traffic
DRIV.VOICE - NATIONAL.Traffic.Voice traffic
DRIV.IPTV - SD channels.Channels.Channels
DRIV.IPTV - HD channels.Channels.Channels
DRIV.IPTV - Radio channels.Channels.Channels

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, retail broadband services should be contained in both the drivers used to dimension the transmission & core network at regional level (i.e. the links between local nodes and service nodes) as well as at national level (i.e. the links between service nodes).

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



List of relationships	
SERVICE (Variable Name)	DRIVER (Variable Name)
Broadband.xDSL.Retail.xDSL retail	DRIV.COPPER - REGIONAL.Traffic.Data traffic
Broadband.xDSL.Wholesale.xDSL resale	DRIV.COPPER - REGIONAL.Traffic.Data traffic
Broadband.xDSL.Wholesale.xDSL bitstream	DRIV.COPPER - REGIONAL.Traffic.Data traffic

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:

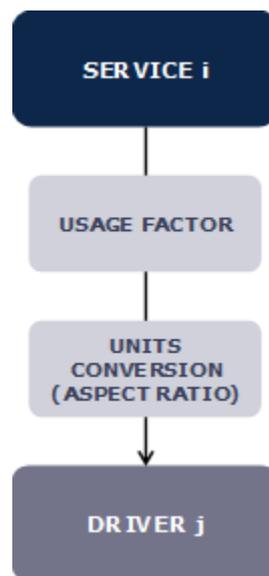


Exhibit 4.3: Conversion Process from Services to Drivers [Source: Axon Consulting]

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:

$$CF = UF * UCF$$



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. voice service in minutes or broadband services in lines) to those used by the driver (e.g. Mbps). This conversion is performed in the worksheet '5A CALC ADJUSTED DEMAND' of the model.



5. Geotypes definition

The design of transport networks requires an extensive analysis of the topology of the network to be covered, as it will have a direct impact on the resources that need to be deployed (e.g., length of fibre cables, number of routers, etc.).

The main purpose of this analysis is to aggregate the characteristics of the nodes located at local level (namely Local Exchanges or Regional Nodes) into geotypes, characterising the nodes covered under each geotype in terms of number of lines and traffic managed by each node. This information is later used for the dimensioning of the transmission and core networks, as described in further detail in section 6.

Therefore, the classification of the Regional nodes into geotypes is based on the available information regarding number of lines and traffic handled by each node. The number of geotypes has been set to ten (10) in order to represent ten different types of Regional nodes.

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

- ▶ Number of lines per node (# of lines/node), i.e. the number of lines connected to each node, including all types of services.
- ▶ Traffic per node (Mbps/node), i.e. the traffic going through each node, including all types of services.

In this respect, the philosophy pursued by the "k-means" algorithm is to define groups or clusters (in this case 10, which will be the geotypes), each of which will contain those nodes with similar characteristics (in this case, these characteristics will be assessed in terms of lines and traffic handled). As a result, each node will be assigned to a cluster, which will include the set of nodes with similar number of lines and traffic. Finally, the model will consider the average characteristics of all nodes belonging to a given geotype as input for the calculations.

The followed process to compute the "k-means" algorithm has comprised three steps:

1. Calculating cluster variables: number of lines and traffic. The number of lines and traffic per node have been calculated considering the aggregation data for the specific services. On the one hand, total lines served by each node comprise active broadband lines (Copper + FTTH/B, retail + wholesale) and active lines related to data connectivity services (VPN and Leased Lines). On the other hand, the total traffic handled by each node comprises the traffic



related to broadband services, IPTV services, voice services and data connectivity services. The source of information employed for this calculation has been the data provided by Proximus for each node.

2. Executing k-means algorithm. The algorithm of Hartigan and Wong (1979)¹ is used by default.
3. Assignment of obtained clusters to each node. Once the ten clusters have been defined based on the global set of nodes and their characteristics, these clusters are assigned to their associated nodes. As a result, a classification of the Regional nodes into geotypes is obtained.

The geotype characterisation shows that the traffic handled per node is highly proportional to the number of served lines, with the exception of a specific number of nodes with a higher proportion of traffic than the average, mainly due to Data Connectivity services.

As a result of the above geotype definition, 10 geotypes have been obtained. This geotype definition is exclusively employed for the dimensioning of the Regional Nodes (see further details on the network design in section 6), given the higher number of them available in the network, what makes unfeasible to consider them individually in the bottom-up modelling approach.

On the other hand, in upper levels of the network (Aggregation Nodes, Service Nodes, etc.), given the lower number of available nodes, the dimensioning is carried out individually for each specific node, without the need of aggregating them into geotypes.

Nevertheless, given that the traffic demand is originated from the Regional Nodes, the calculation of the traffic flowing towards the upper levels of the network is calculated taking into account the connections existing between the different nodes of the network, using tables such as the one presented below (reflected in worksheet "2B INP NW CHARACTER"):

¹ More details in: <https://www.tqmp.org/RegularArticles/vol09-1/p015/p015.pdf>



AGGREGATION NODES

Aggregation Nodes	# of Regional Nodes connected to each Aggregation Node			
	GEOTYPE 1	GEOTYPE 2	GEOTYPE 3	GEOTYPE 4
Aggregation Node 1	-	-	-	3
Aggregation Node 2	-	-	-	3
Aggregation Node 3	-	-	-	-
Aggregation Node 4	-	-	-	-
Aggregation Node 5	1	-	-	-
Aggregation Node 6	-	1	-	4
Aggregation Node 7	1	1	-	4

Figure 5.1: Example of connections between Aggregation Nodes and Regional Nodes [Source: Axon Consulting]

As can be observed from the table above, for instance, Aggregation Node 7 is connected to a Regional Node belonging to Geotype 1, a Regional Node belonging to Geotype 2, and 4 Regional Nodes belonging to Geotype 4. As a consequence, the Aggregation Node 7 will aggregate the traffic of all these previous Regional Nodes.



6. Dimensioning Module

The Dimensioning Module aims at designing the transmission and core network, calculating the number of network resources required to serve the demand level of the reference operator.

This module is responsible for dimensioning the required equipment in the transmission and core network needed to handle the traffic demand going from the access network through the Regional Nodes (located at the local level) to the Central Service Nodes and Data Center Nodes (located at national level).

The transmission and core network modelled may be divided into three different main sections, depending on the network elements that are linked, as described below:

- ▶ *LOCAL*: This part of the network connects the Regional Nodes with the Aggregation Nodes of the operator.
- ▶ *REGIONAL*: This part of the network connects the Aggregation Nodes with the Service Nodes of the operator. It is worth outlining that Regional Nodes can also be connected directly to Service Nodes, thus without going through an intermediate Aggregation Node.
- ▶ *NATIONAL*: This part of the network represents the connections between the Service Nodes, Central Service Nodes and Data Center Nodes.

According to the reality of Proximus, ring topologies have been considered for the network connections at local and regional level, while a fully meshed topology has been considered at national level. An illustrative representation of the transmission and core network considered is provided in the exhibit below:

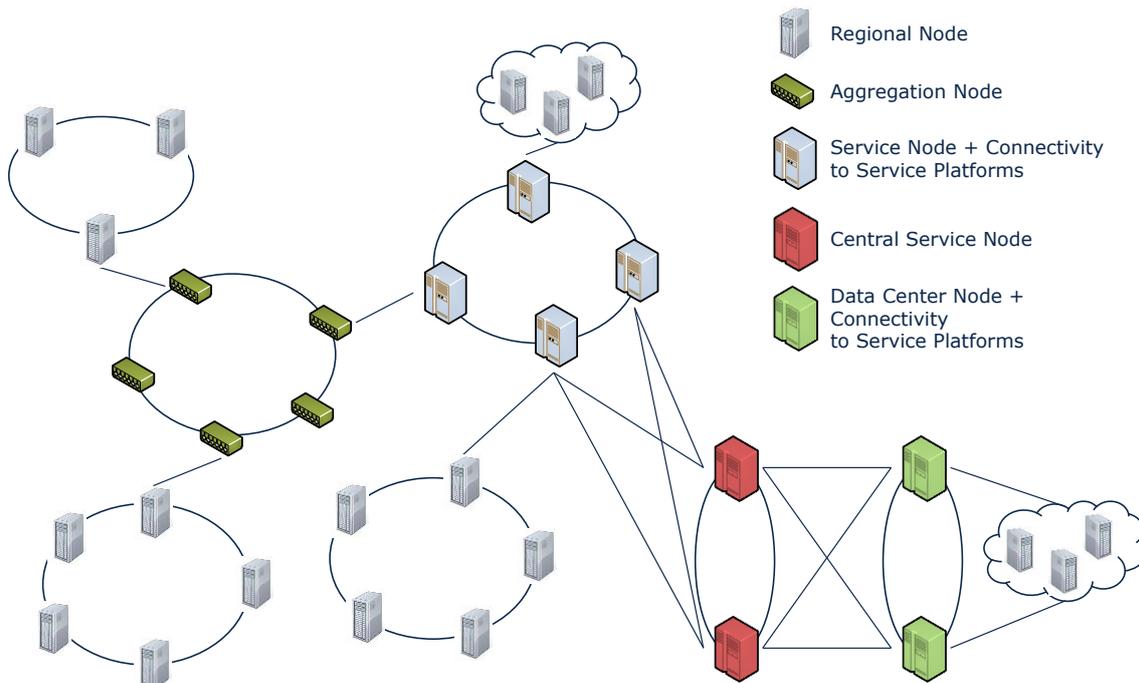


Figure 6.1: Overview of the general architecture considered in the transmission and core network [Source: Axon Consulting]

The characteristics of the transmission links and the position of the network elements have been provided by Proximus. This information determines the length of the fibre rings in the network and the connection between nodes.

The dimensioning of the transmission links considers the fibre technology divided by different configurations (1 strand per cable, 2 strands per cable, 4 strands per cable, etc.).

On the other hand, the dimensioning of the network equipment considers the traffic demand generated by the subscribers. This traffic can circulate through the links and network elements in both directions, either towards the end users connected to the Regional Nodes or towards the core nodes and service platforms. Based on this, the traffic that circulates through each link and network element depends on how the different nodes belonging to network sections (Local, Regional or National) are connected among them.

The dimensioning algorithm that has been followed in the design of the transmission and core network is organised into ten (10) steps as shown below:

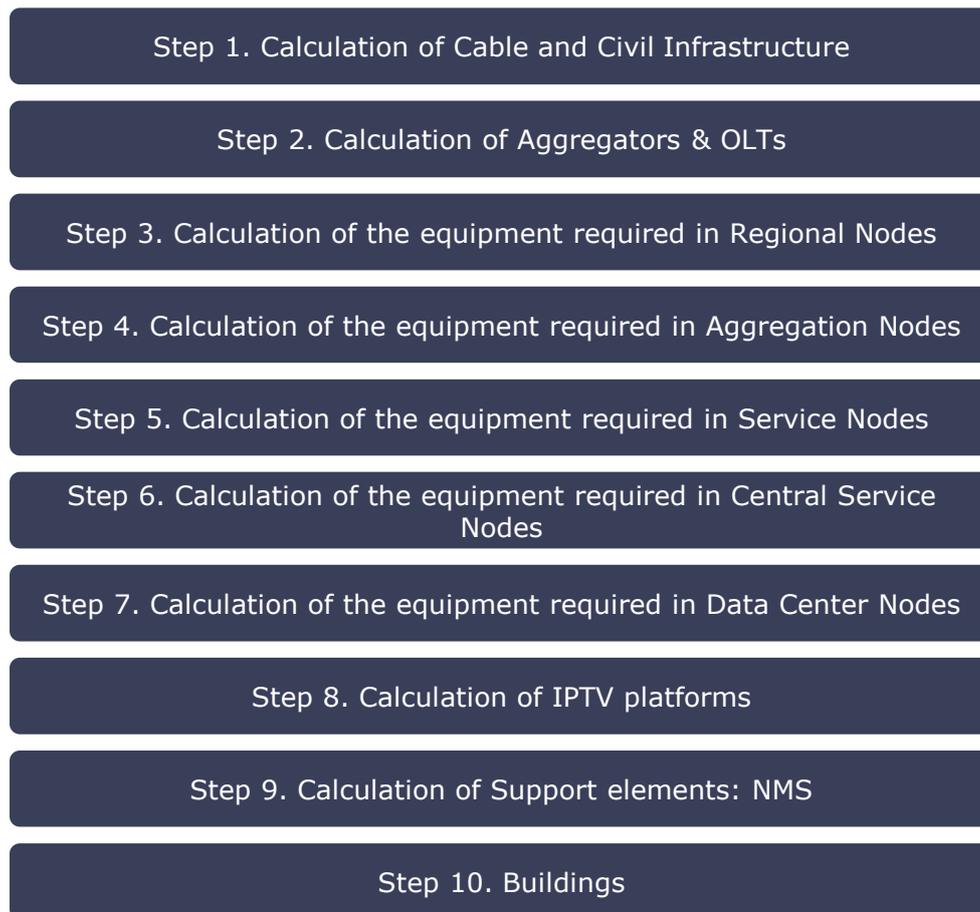


Figure 6.2: Steps for Transmission and Core Network Dimensioning [Source: Axon Consulting]

6.1. Step 1: Calculation of Cable and Civil Infrastructure

As a first step, the Model calculates the length of the fibre cable and the civil infrastructure elements that will be required.

On the one hand, the length of fibre cables required for each configuration is calculated based on the total fibre cable length per section of the network (Local/Regional and National) and the proportion in which the total fibre deployed by the reference operator is distributed among the different configurations. The figure below illustrates the calculation algorithm:

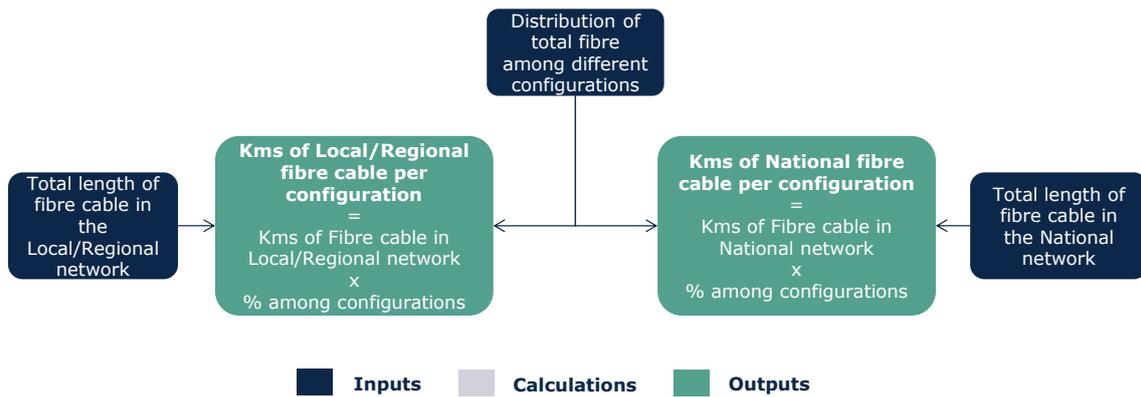


Figure 6.3: Calculation of the fibre cable configurations [Source: Axon Consulting]

On the other hand, with respect to trenches, their corresponding length per section of the network (Local/Regional and National) is calculated based on the total length of trenches, considering their sharing with other non-relevant networks belonging to the modelled operator (fixed access, mobile backhauling, etc.) as well as with other networks belonging to external parties (alternative operators and/or utilities). In addition, it is also considered the proportion of fibre cables previously allocated to Local/Regional and National regions.

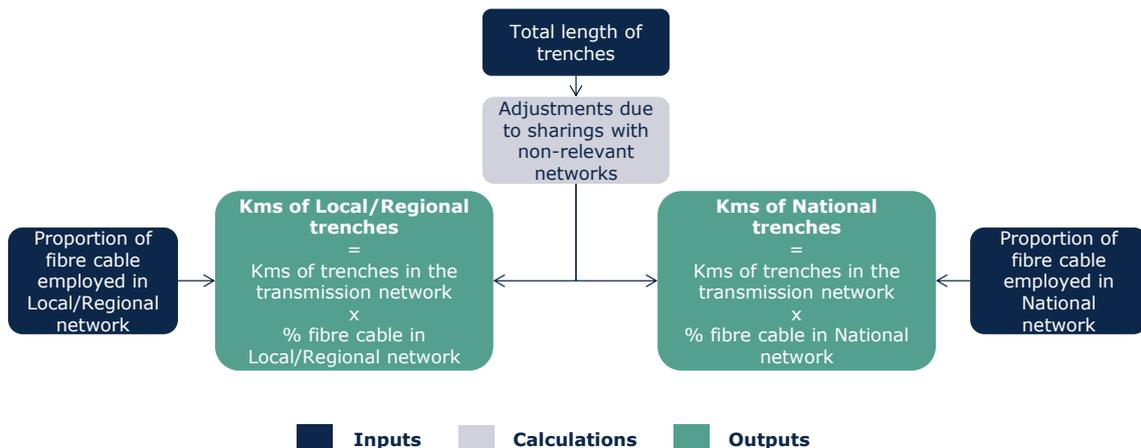


Figure 6.4: Calculation of the trenches [Source: Axon Consulting]

Finally, based on the fibre cable and trench lengths previously calculated, the elements of manholes, ODFs and signal amplifiers are dimensioned:

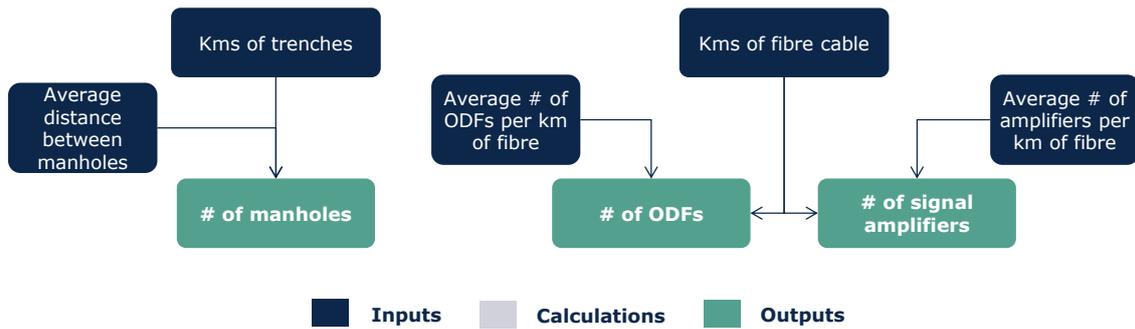


Figure 6.5: Calculation of the manholes, ODFs and signal amplifiers [Source: Axon Consulting]

6.2. Step 2: Aggregators & OLTs

The Aggregators are calculated based on the average xDSL lines connected the Regional Node, and the average number of lines that can be connected to one Aggregator. On top of these xDSL lines, the Data Connectivity lines that are directly connected to the Aggregators are also considered. The figure below illustrates the calculation algorithm:

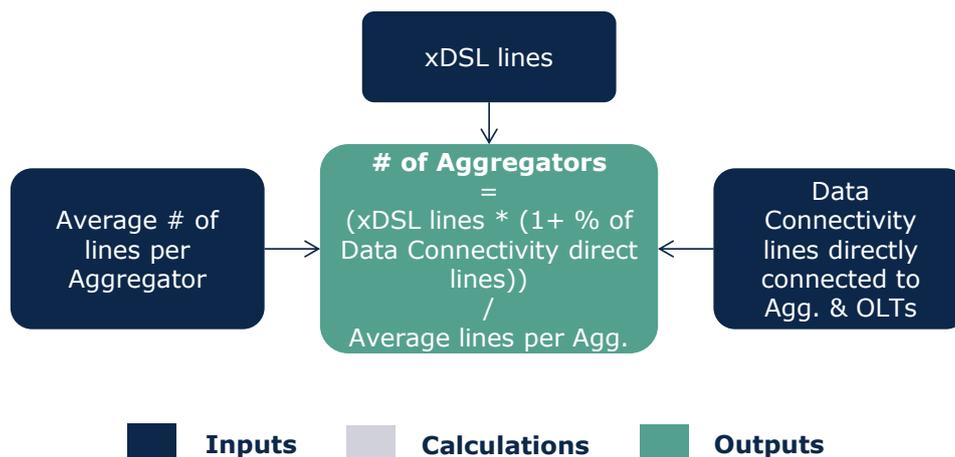


Figure 6.6: Calculation of the Aggregators [Source: Axon Consulting]

With respect to OLTs, the model differentiates between OLTs related to own network of Proximus and OLTs related to Joint Ventures established between Proximus and other parties.

Following Proximus' designs, OLTs related to the own network are calculated based on the yearly homes passed by its own FTTH/B network², while OLTs related to the Joint Ventures³ are calculated based on FTTH/B active lines connected through such

² It must be noted that Proximus' own FTTH/B networks follow a P2MP solution where, therefore, patching/reassignment after deployment is limited.

³ It must be noted that Proximus' Joint Ventures networks follow a P2P solution, what increases the flexibility and possibility to scale up and reconnect/repach lines for optimizing the OLT usage.



Joint Ventures. Finally, the Data Connectivity lines that are directly connected to the OLTs are also considered, as it is shown in the following calculation algorithm:

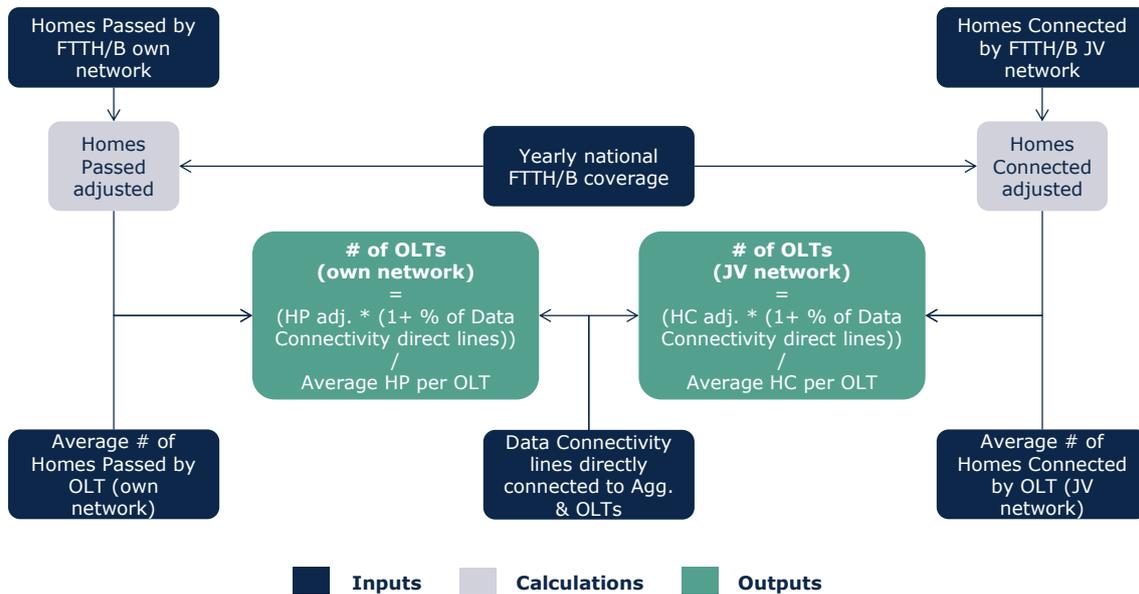


Figure 6.7: Calculation of the OLTs (own and JV networks) [Source: Axon Consulting]

Finally, we also note that the unit cost of the OLTs and the Aggregators is set to zero in the model, as these elements are already recovered by means of the access rental fee, thus, they should not be recovered by means of the Ethernet transport tariffs.

6.3. Step 3: Regional Nodes

The dimensioning of the Regional Nodes is divided into two steps:

- ▶ Router equipment dimensioning
- ▶ DWDM equipment dimensioning

6.3.1. Router equipment dimensioning

As a first step, the routers located in the Regional Nodes, the I-edge routers, are dimensioned considering the traffic handled by each Regional Node. This calculation is performed at level of geotype.

On the one hand, access-facing ports are dimensioned by considering such handled traffic and the capacity of the available ports (1G or 10G ports), also reserving additional ports for the specific PSTN and Data Connectivity services which are directly connected to the I-edge router (i.e. they are not firstly connected to the aggregator or OLT).



On the other hand, the calculation of the core-facing ports follows a similar approach, dividing the total traffic handled by each Regional Node by the capacity of the ports used, in this case 10G ports, in order to obtain the number of required core-facing ports.

Once the needed ports per Regional Node are obtained, they are aggregated to calculate the necessary ports cards and chassis for the I-edge routers, by considering their maximum capacity (i.e., the maximum ports capacity of the cards and the maximum cards capacity of the chassis).

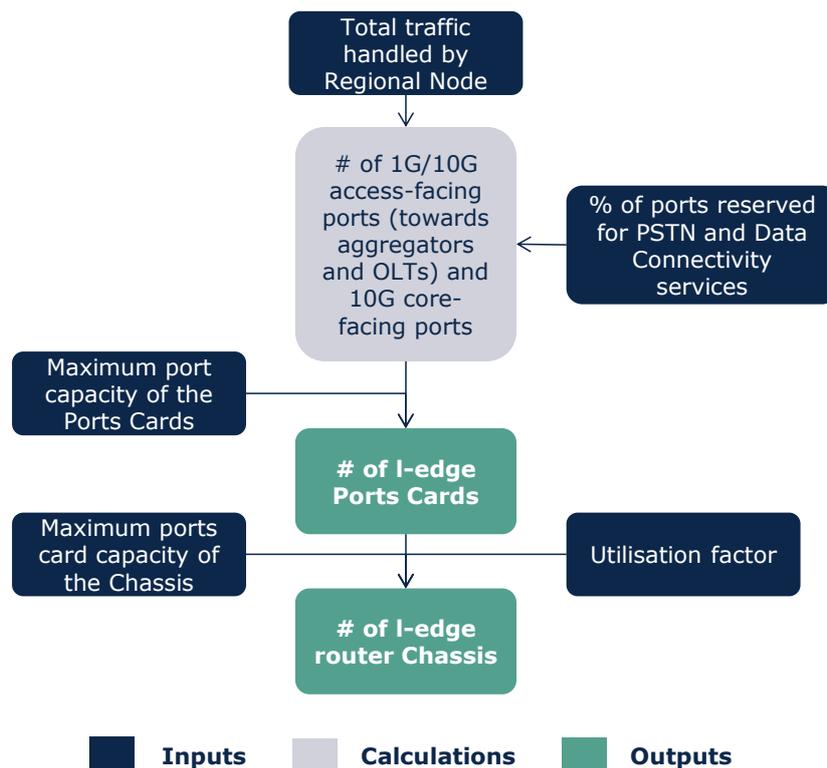


Figure 6.8: Dimensioning of the router equipment in the Regional Nodes [Source: Axon Consulting]

6.3.2. DWDM equipment dimensioning

The relevant DWDM equipment in the Regional Nodes are the 10G transponders and the Add-Drop Multiplexers (ADMs).

Firstly, the 10G transponders are obtained by assigning one transponder per core-facing 10G port.

Then, once the transponders have been calculated, the ADMs are obtained by dividing the necessary number of transponders per Regional Node by the maximum transponder capacity of the ADM.

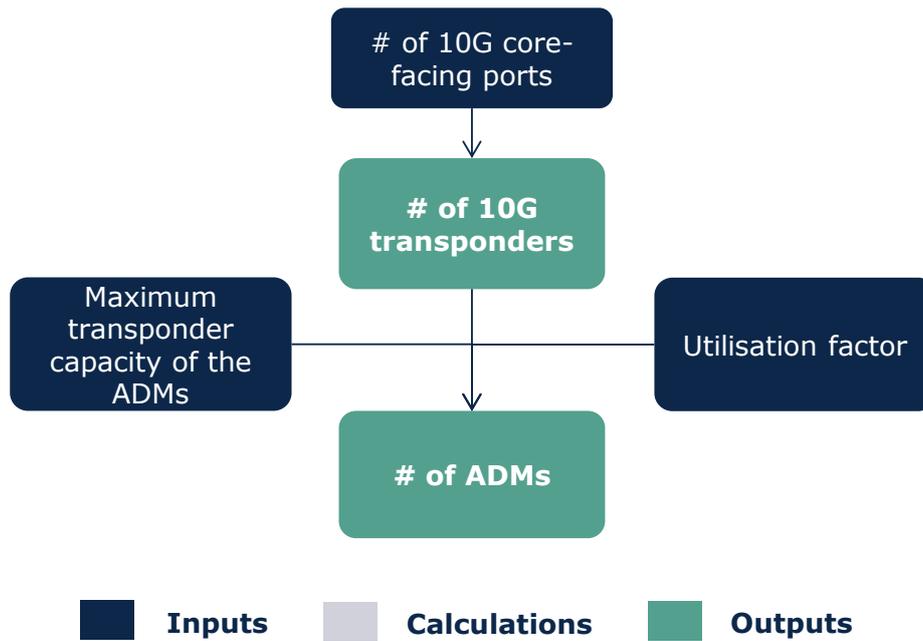


Figure 6.9: Dimensioning of the DWDM equipment in the Regional Nodes [Source: Axon Consulting]

6.4. Step 4: Aggregation Nodes

The dimensioning of the Aggregation Nodes is divided into two steps:

- ▶ Router equipment dimensioning
- ▶ DWDM equipment dimensioning

6.4.1. Router equipment dimensioning

As a first step, the routers located in the Aggregation Nodes, the a-core routers, are dimensioned considering the traffic handled by each Aggregation Node, whose handled traffic should be equivalent to the sum of traffics handled by all connected Regional Nodes to each individual Aggregation Node.

On the one hand, the access-facing ports in each Aggregation Node are equivalent to the sum of all core-facing 10G ports of all the routers installed in the Regional Nodes (i.e., l-edge routers) that are connected to that Aggregation Node.

On the other hand, the number of core-facing ports necessary in each Aggregation Node are calculated by dividing the total traffic handled by each Aggregation Node by the capacity of the core-facing ports, in this case 100G.

Finally, once all the necessary ports per Aggregation Node are obtained, they are aggregated to calculate the necessary cards and chassis for the a-core routers, by



considering their maximum capacity (i.e., the maximum ports capacity of the cards and the maximum cards capacity of the chassis).

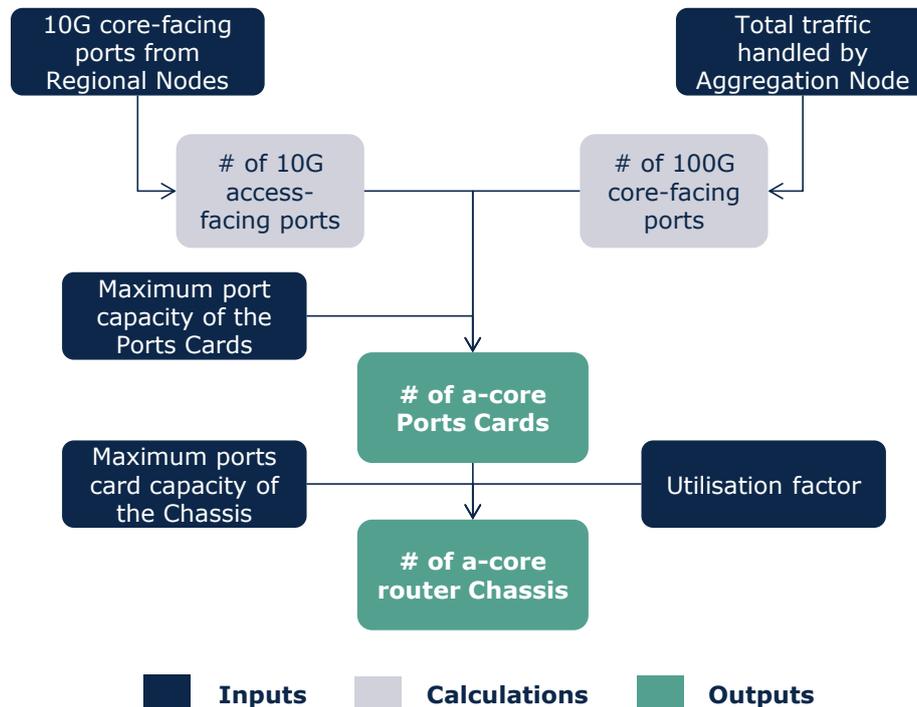


Figure 6.10: Dimensioning of the router equipment in the Aggregation Nodes [Source: Axon Consulting]

6.4.2. DWDM equipment dimensioning

The relevant DWDM equipment in the Aggregation Nodes are the 10G/100G transponders and the Terminal Multiplexers (TMUXs).

Firstly, the 10G and 100G transponders are obtained by assigning one 10G transponder per access-facing 10G port and one 100G transponder per core-facing 100G port, respectively.

Then, once the transponders have been calculated, the TMUXs are obtained by dividing all the necessary number of transponders per Aggregation Node by the maximum transponder capacity of the TMUX.

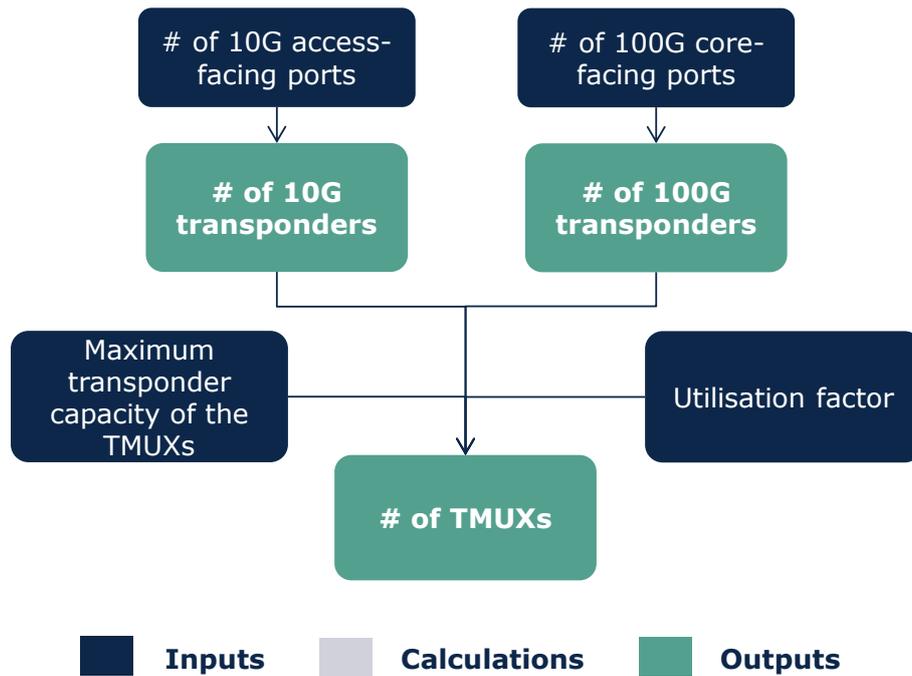


Figure 6.11: Dimensioning of the DWDM equipment in the Aggregation Nodes [Source: Axon Consulting]

6.5. Step 5: Service Nodes

The dimensioning of the Service Nodes is divided into two steps:

- ▶ Router equipment dimensioning
- ▶ DWDM equipment dimensioning

6.5.1. Router equipment dimensioning

The Service Nodes host 2 types of routers: the s-core routers, which are the ones connected to the DWDM network, and the s-edge routers, through which the traffic is routed to the service platforms.

S-core routers

The s-core routers are dimensioned considering the traffic handled by each Service Node, whose traffic is equivalent to the sum of traffics handled by all Aggregation Nodes connected to it, plus the sum of traffics handled by all the Regional Nodes that are directly connected to that Service Node (without an intermediate Aggregation Node).

Therefore, the access-facing ports in each Service Node are equivalent to the sum of:



- ▶ All the core-facing 100G ports of all the routers installed in the Aggregation Nodes (i.e., a-core routers) that are connected to that Service Node, plus
- ▶ All the core-facing 10G ports of all the routers installed in the Regional Nodes (i.e., l-edge routers) that are directly connected to that Service Node.

On the other hand, the number of core-facing ports necessary in each Service Node is calculated by dividing the total traffic handled by each Service Node by the capacity of the core-facing ports (100G).

Additionally, the service platforms-facing ports in each Service Node are calculated by dividing the specific portion of traffic handled by the Service Node that goes towards the service platforms by the capacity of the service platforms-facing ports (100G).

Finally, once all the necessary ports per Service Node are obtained, they are aggregated to calculate the necessary ports cards and chassis for the s-core routers by considering their maximum capacity (i.e., the maximum ports capacity of the cards and the maximum cards capacity of the chassis).

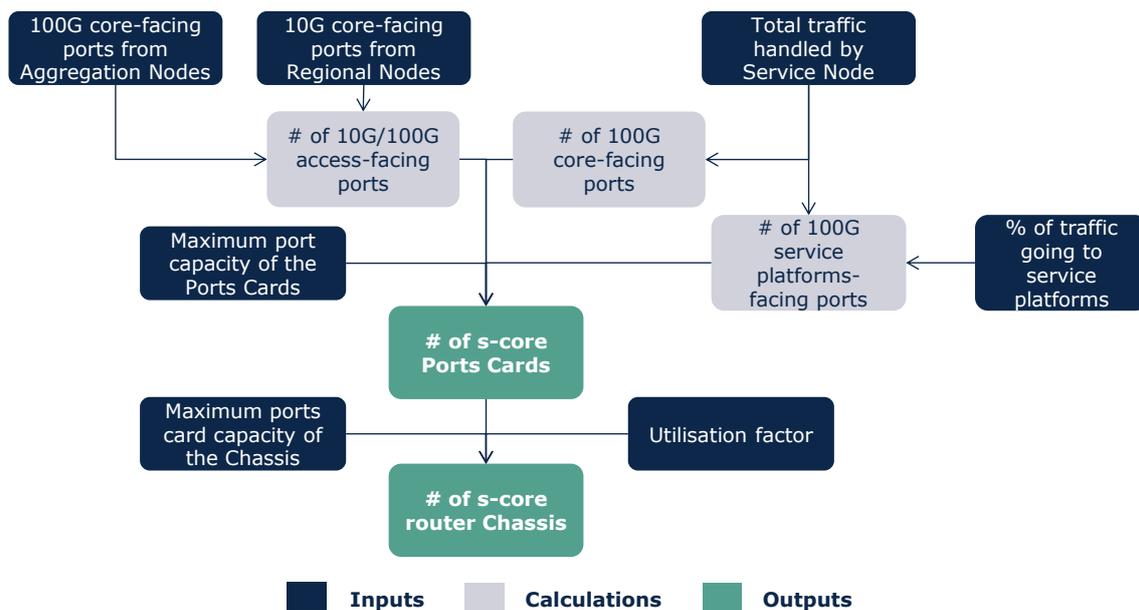


Figure 6.12: Dimensioning of the s-core router equipment in the Service Nodes [Source: Axon Consulting]

S-edge routers

The s-edge routers are dimensioned considering the specific portion of traffic coming from the connected Service Node that goes towards the service platforms.



On the one hand, the core-facing ports in each s-edge router are equivalent to the sum of all the service platforms-facing 100G ports of all routers installed in the Service Node (i.e., s-core routers) that is connected to that s-edge router.

On the other hand, the number of service platforms-facing ports necessary in each s-edge router is calculated by dividing the traffic coming from the connected Service Node by the capacity of the service platforms-facing ports (1G or 100G), differentiating by the type of traffic assigned to each capacity. Specifically:

- ▶ The voice traffic uses 1G ports, and
- ▶ The remaining traffic uses 100G ports.

Finally, once all the necessary ports to handle the service platforms traffic are obtained, they are aggregated to calculate the necessary ports cards and chassis for the s-edge routers by considering their maximum capacity (i.e., the maximum ports capacity of the cards and the maximum cards capacity of the chassis).

In addition to this, a redundancy of 3 s-edge routers per each Service Node has been applied on top to calculate to total number of s-edge routers in the network.

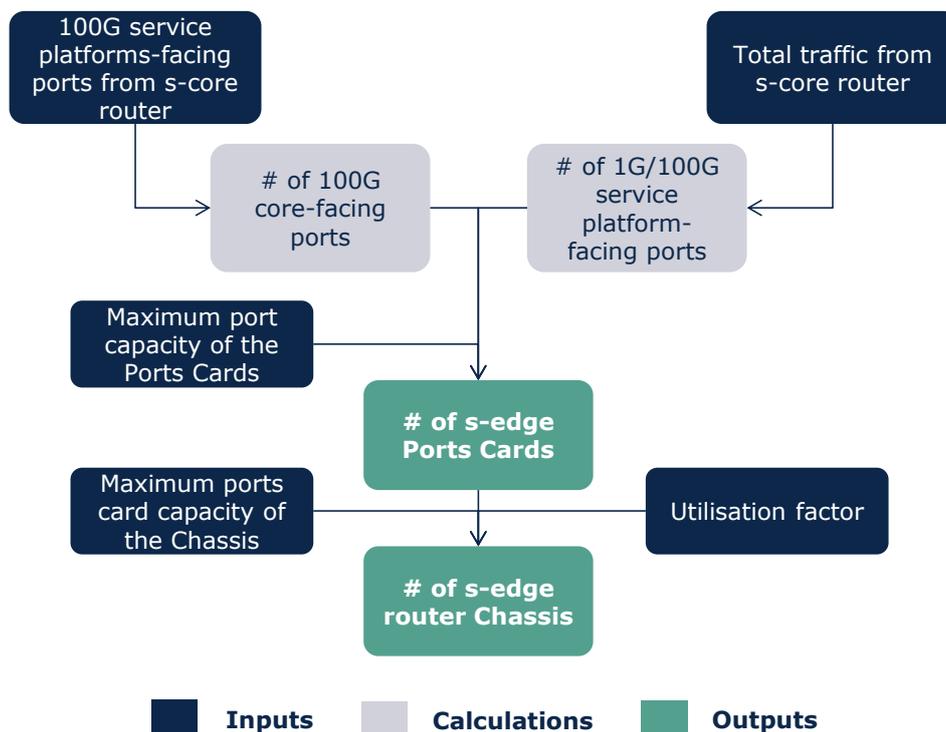


Figure 6.13: Dimensioning of the s-edge router equipment in the Service Nodes [Source: Axon Consulting]



6.5.2. DWDM equipment dimensioning

The relevant DWDM equipment in the Service Nodes are the 10G/100G transponders, the Terminal Multiplexers (TMUXs) and the Cross-Connects (XCOs).

Firstly, the 10G and 100G transponders are obtained by assigning one 10G transponder per access-facing 10G port and one 100G transponder per each 100G port (access-facing or core-facing port), respectively.

Then, once the transponders have been calculated, the TMUXs are obtained by dividing the necessary number of transponders per Service Node by the maximum transponder capacity of the TMUX. In this regard, access-facing transponders and core-facing transponders have been differentiated in order to obtain access-facing TMUXs and core-facing TMUXs, respectively, since only the latter are connected to the XCOs.

Therefore, the XCOs are obtained by dividing the core-facing TMUXs previously calculated by the maximum TMUX capacity of the XCO, differentiating between the possible options in terms of XCO positions (4, 6 or 8) depending on the number of inbound/outbound directions of each Service Node.

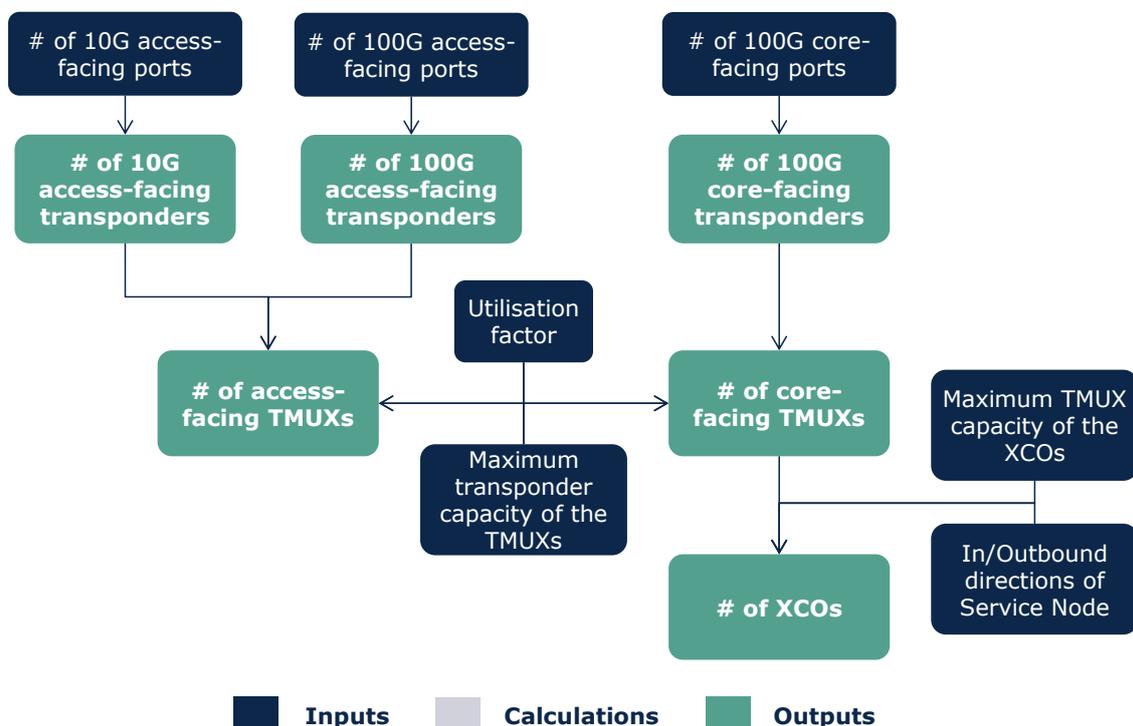


Figure 6.14: Dimensioning of the DWDM equipment in the Service Nodes [Source: Axon Consulting]



6.6. Step 6: Central Service Nodes

The dimensioning of the Central Service Nodes is divided into two steps:

- ▶ Router equipment dimensioning
- ▶ DWDM equipment dimensioning

6.6.1. Router equipment dimensioning

As a first step, the routers located in the Central Service Nodes, the c-core routers, are dimensioned considering the traffic handled by each Central Service Node, which is equivalent to sum of traffics handled by all Service Nodes connected to it.

On the one hand, the access-facing ports in each Central Service Node are equivalent to the sum of all the core-facing 100G ports of all the routers installed in the Service Nodes (i.e., s-core routers) that are connected to that Central Service Node.

On the other hand, the number of core-facing ports necessary in each Central Service Node are calculated by dividing the total traffic handled by each Central Service Node by the capacity of the core-facing ports (100G).

Finally, once all the necessary ports per Central Service Node are obtained, they are aggregated in order to calculate the necessary ports cards and chassis for the c-core routers by considering their maximum capacity (i.e., the maximum ports capacity of the cards and the maximum cards capacity of the chassis).

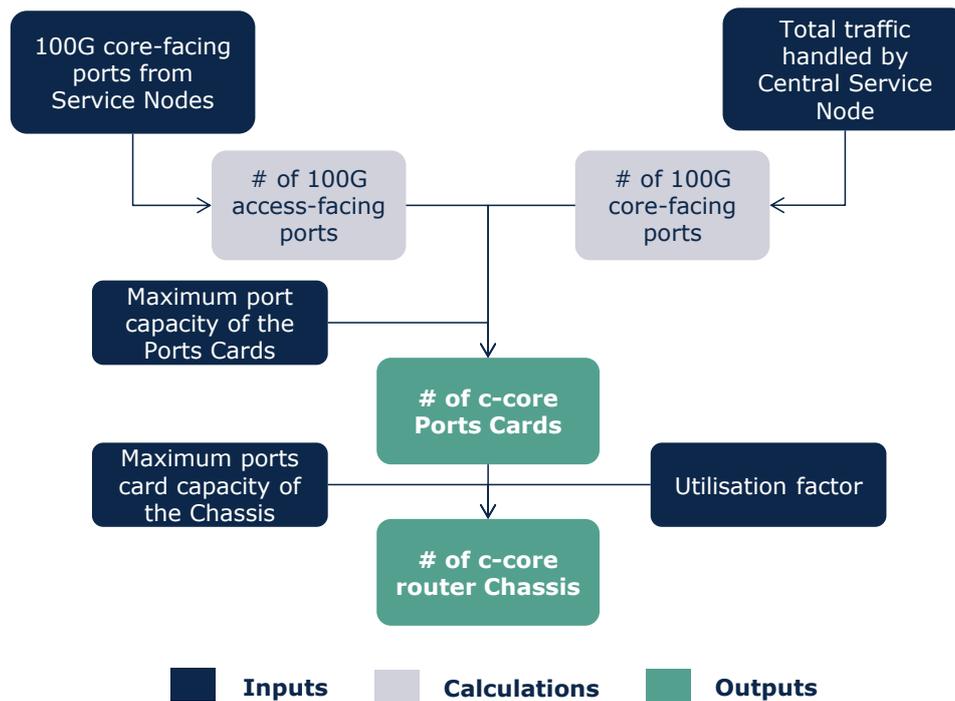


Figure 6.15: Dimensioning of the router equipment in the Central Service Nodes [Source: Axon Consulting]

6.6.2. DWDM equipment dimensioning

The relevant DWDM equipment in the Central Service Nodes are the 100G transponders, the Terminal Multiplexers (TMUXs) and the Cross-Connects (XCOs).

Firstly, the 100G transponders are obtained by assigning one 100G transponder per each 100G port (access-facing or core-facing port).

Then, once the transponders have been calculated, the TMUXs are obtained by dividing the necessary number of transponders per Central Service Node by the maximum transponder capacity of the TMUX.

Finally, the XCOs are obtained by dividing the TMUXs previously calculated by the maximum TMUX capacity of the XCO, differentiating between the possible options in terms of XCO positions (4, 6 or 8) depending on the number of inbound/outbound directions of each Central Service Node.

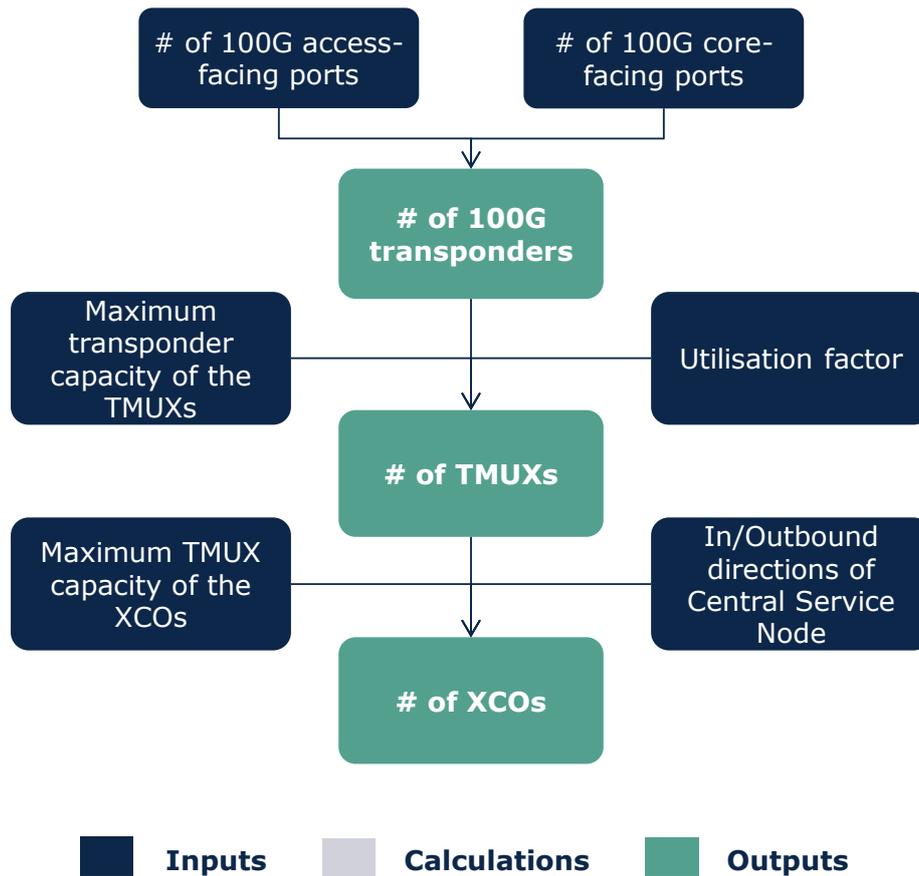


Figure 6.16: Dimensioning of the DWDM equipment in the Central Service Nodes [Source: Axon Consulting]

6.7. Step 7: Data Center Nodes

The dimensioning of the Data Center Nodes is divided into two steps:

- ▶ Router equipment dimensioning
- ▶ DWDM equipment dimensioning

6.7.1. Router equipment dimensioning

As a first step, the routers located in the Data Center Nodes, the d-core routers, are dimensioned considering the traffic handled by each Data Center Node, which is equivalent to the total traffic handled by all connected Central Service Nodes.

On the one hand, the access-facing ports in each Data Center Node are equivalent to the sum of all the core-facing 100G ports of all the routers installed in the Central Service Nodes (i.e., c-core routers) that are connected to that Data Center Node.

On the other hand, the number of service platforms-facing ports necessary in each Data Center Node are calculated by dividing the portion of the traffic routed to service



platforms by the capacity of the service platforms-facing ports (1G or 100G), differentiating by the type of traffic assigned to each capacity. Specifically:

- ▶ The voice traffic uses 1G ports, and
- ▶ The remaining traffic uses 100G ports.

Finally, once all the necessary ports per Data Center Node are obtained, they are aggregated in order to calculate the necessary ports cards and chassis for the d-core routers by considering their maximum capacity (i.e., the maximum ports capacity of the cards and the maximum cards capacity of the chassis).

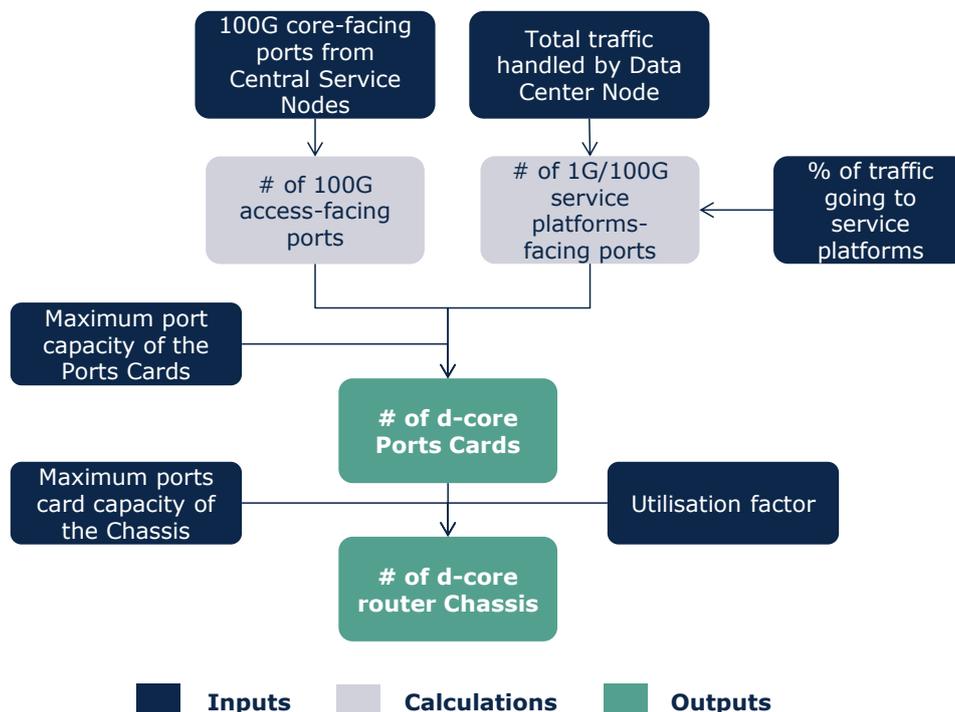


Figure 6.17: Dimensioning of the router equipment in the Data Center Nodes [Source: Axon Consulting]

6.7.2. DWDM equipment dimensioning

The relevant DWDM equipment in the Data Center Nodes are the 100G transponders, the Terminal Multiplexers (TMUXs) and the Cross-Connects (XCOs).

Firstly, the 100G transponders are obtained by assigning one 100G transponder per each access-facing 100G port.

Then, once the transponders have been calculated, the TMUXs are obtained by dividing the necessary number of transponders per Data Center Node by the maximum transponder capacity of the TMUX.



Finally, the XCOs are obtained by dividing the TMUXs previously calculated by the maximum TMUX capacity of the XCO, differentiating between the possible options in terms of XCO positions (4, 6 or 8) depending on the number of inbound/outbound directions of each Data Center Node.

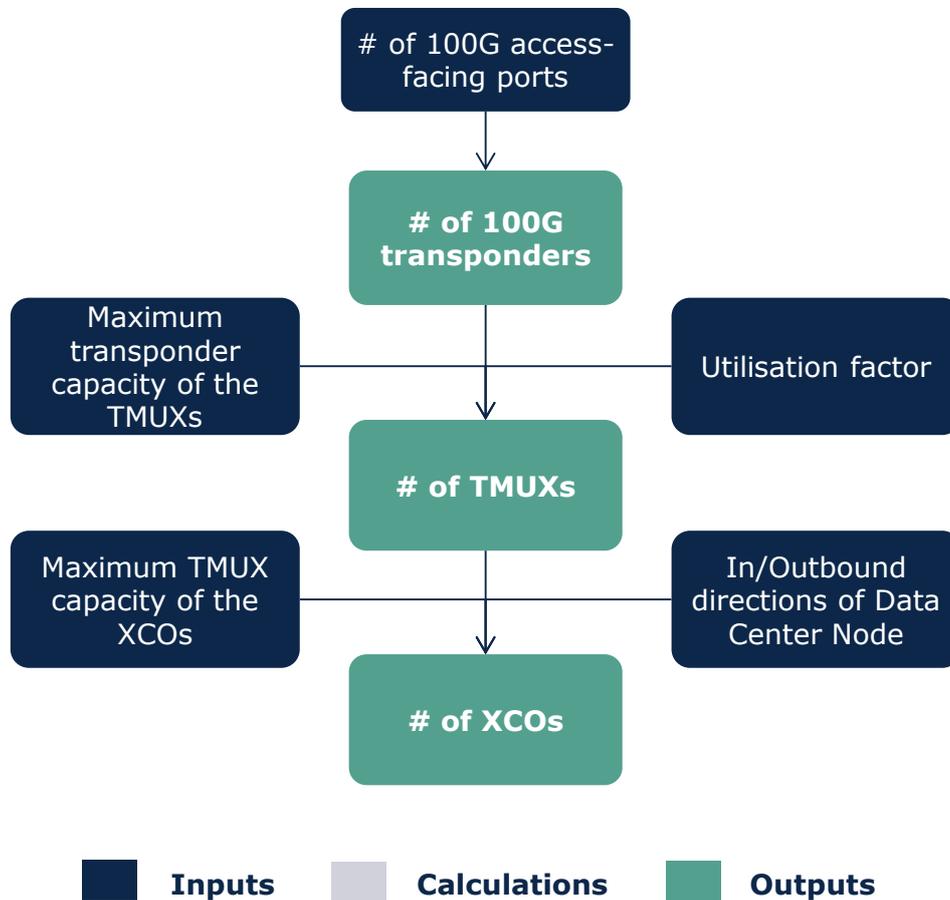


Figure 6.18: Dimensioning of the DWDM equipment in the Data Center Nodes [Source: Axon Consulting]

6.8. Step 8: IPTV platforms

The IPTV platforms are dimensioned by considering the number of IPTV channels, differentiating by each type of channel (HD, SD and Radio IPTV channels).

With respect to the Video on Demand (VoD) platform, it is necessary a VoD platform as long as there is VoD traffic.

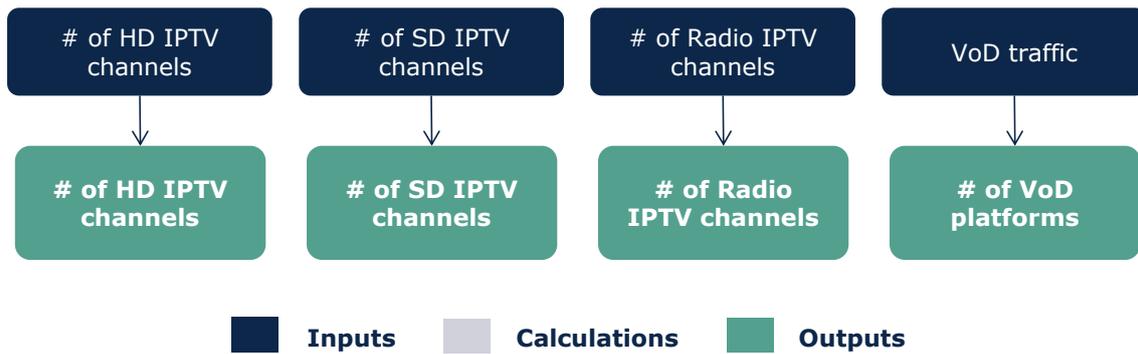


Figure 6.19: Dimensioning of the IPTV platforms [Source: Axon Consulting]

6.9. Step 9: Support elements: NMS

The Network Management System (NMS) is dimensioned assuming that at least one NMS in the network is necessary to manage all the network elements.

6.10. Step 10: Buildings

As a final step, the number of buildings that are necessary to host all the network nodes is dimensioned. In this regard, these buildings are categorised equivalently to the associated nodes into 5 types:

- ▶ Buildings for Regional Nodes
- ▶ Buildings for Aggregation Nodes
- ▶ Buildings for Service Nodes
- ▶ Buildings for Central Service Nodes
- ▶ Buildings for Data Centre Nodes.

The number of buildings of each type is equal to the number of associated nodes, adjusting this number by a 1/3 factor in order to exclude the space in these buildings that is occupied by other equipment not relevant to the modelled services (e.g. access equipment of other specific service-platforms).



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.

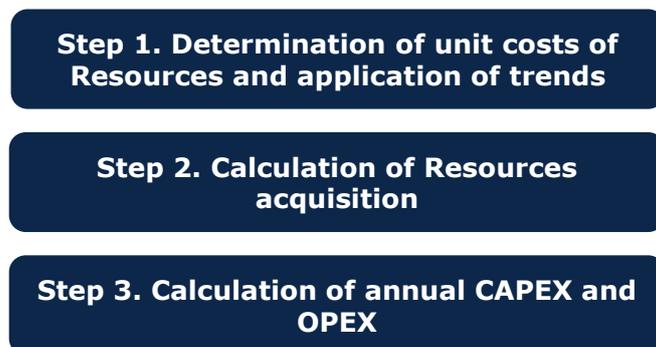


Exhibit 7.1: Resources Costing [Source: Axon Consulting]

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 current year. This information is introduced in the worksheet '1B 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 '1C 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.

$$\text{Unit Cost (year)} = \text{Unit Cost (year - 1)} * (1 + \text{Trend (year)})$$



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:

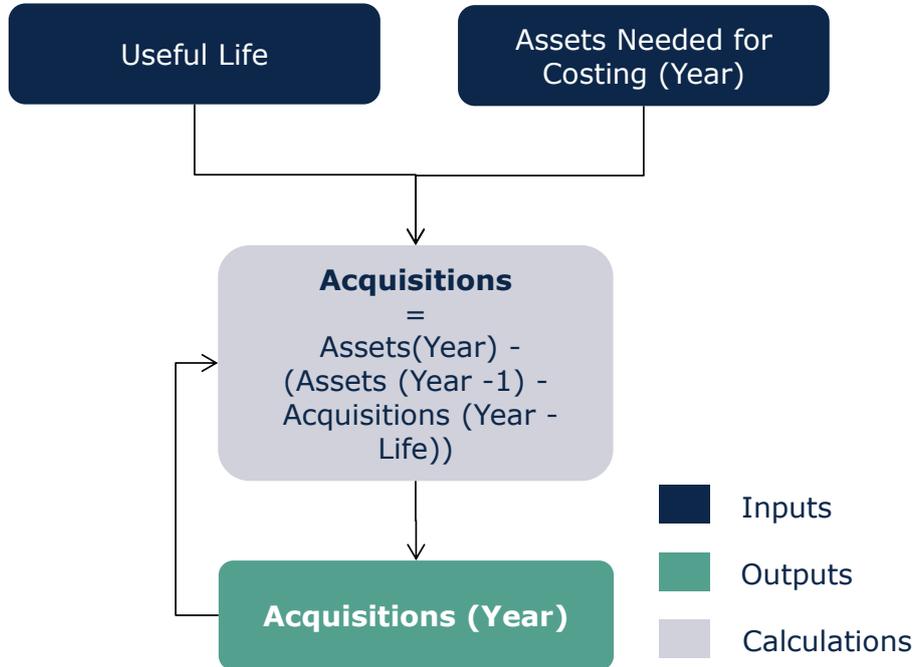


Exhibit 7.2: Algorithm for the Calculation of New Acquisitions [Source: Axon Consulting]

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

- ▶ **Network deployment:** The 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 CAPEX (before annualization) and OPEX (before annualization) follows the algorithm:

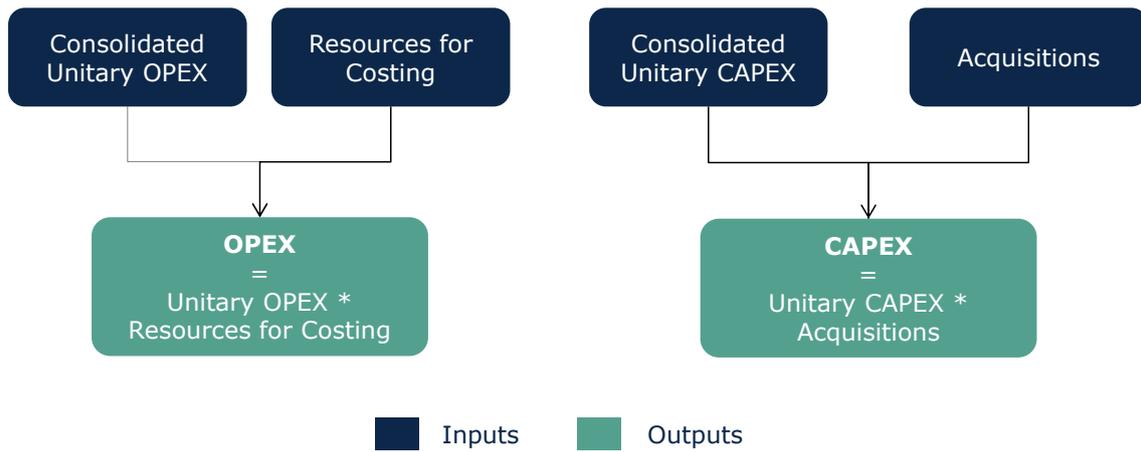


Exhibit 7.3: Algorithm for the Calculation of the CAPEX and OPEX [Source: Axon Consulting]



8. Depreciation Module

The Depreciation Module aims at calculating the annualisation method to distribute CAPEX and OPEX over the years (annualisation). Therefore, this section presents the economic depreciation method, whose objective 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 from 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 of traffic), 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:

$$c_i = I \cdot \frac{p_i \cdot f_i}{\sum_{n=i_0}^{i_0+UL-1} (p_n \cdot \alpha_n \cdot f_n)}$$

Where:

- ▶ I is the yearly investment associated to the asset. This figure shall include the OpEx that would be incurred in order to operate and maintain the asset throughout its lifetime.
- ▶ c_i is the annualised costs at year i (within the useful life)
- ▶ f_i is the production factor that can be associated with the asset in year i , in terms of average demand per asset
- ▶ p_i is the reference price of the asset for the year i
- ▶ UL is the useful life of the asset
- ▶ i_0 is the year when the asset was purchased
- ▶ α_i represents the cost of capital factor and responds to the following formula:

$$\alpha_i = (1 + WACC)^{-(i-i_0+1)}$$



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:

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

Where F is the formula that represents the LRIC+ model (which calculates the cost according to demand) and v_i represents the demand volume of increment i .

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'), one increment has been defined: Conveyance. Services are then assigned to this increment in Sheet '0A PAR SERVICES'.

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

$$COMMON\ COST = TOTAL\ COSTS - INCREMENTAL\ COSTS$$

In the model, resources' incremental costs are calculated in sheet '8B CALC RES COST CONSOL' while common costs are shown in sheet '10A 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

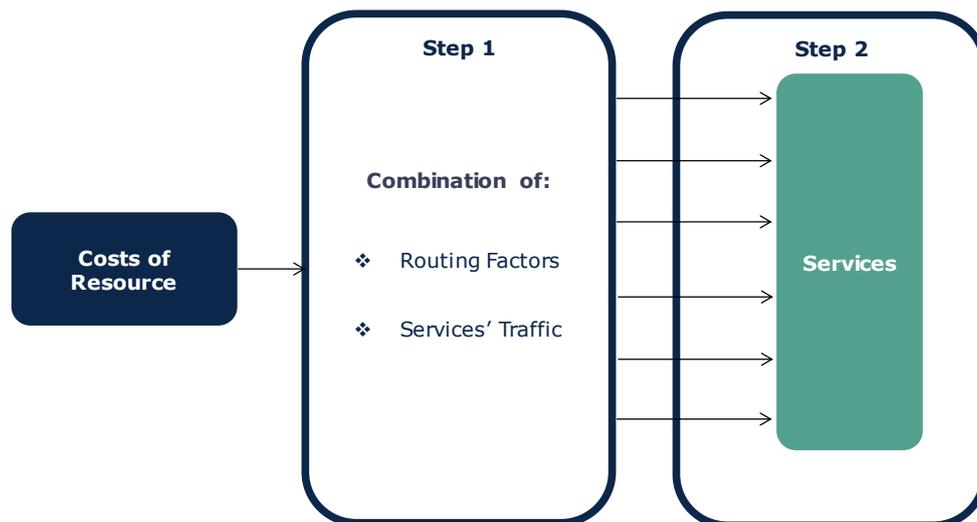


Exhibit 9.1: Cost Imputation Process using Routing Factors [Source: Axon Consulting]

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 IT 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	Service CATEGORY	Service SUBCATEGORY	Service SEGMENT	Service DESCRIPTION	Routing Factor
Fibre cables - Regional	Broadband	xDSL	Retail	xDSL retail	1,00
Fibre cables - Regional	Broadband	xDSL	Wholesale	xDSL resale	1,00
Fibre cables - Regional	Broadband	xDSL	Wholesale	xDSL bitstream	1,00
Fibre cables - Regional	Broadband	FTTH/B	Retail	FTTH/B retail	1,00

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 '9B CALC SERV INCR COST' and, where the formula used allows the implementation of steps described under this section 9.2.