



Excellence in Business



**Assessment of the cost of providing  
wholesale voice call termination services  
on fixed networks in the EU/EEA  
countries – SMART 2018/0014**

**Descriptive manual**

Axon Partners Group

6 May 2019

This document was prepared by Axon Partners Group for the sole use of the client to whom it is addressed. No part of it may be copied without Axon Partners Group prior written consent.



# Contents

Contents .....	1
1. Introduction .....	3
2. Dimensioning Drivers .....	5
2.1. Mapping services to drivers .....	5
2.2. Converting traffic units into the driver units .....	6
2.3. Calculation of dimensioning drivers .....	8
3. Dimensioning Module.....	9
3.1. Step 1. Estimation of the relevant demand for the dimensioning of the core platform .....	11
3.2. Step 2. Number of nodes .....	12
3.3. Step 3. Calculation of the capacity required per node .....	12
3.4. Step 4. Dimensioning of the Hardware component .....	13
3.4.1 Dimensioning based on the Discrete Prices Catalogues Scenario .....	13
3.4.2 Dimensioning based on the Continuous Functions (Curves) Scenario .....	15
3.5. Step 5. Dimensioning of the Software component .....	18
3.6. Step 6. Calculation of total CapEx .....	18
4. OPEX and CAPEX costing module .....	20
4.1. Definition of unitary costs and trends .....	20
4.2. OpEx .....	20
4.3. CapEx.....	21
5. Cost allocation to voice fixed termination services .....	23
5.1. Incremental costs .....	23



5.2. Wholesale specific costs .....	24
Annex A. Detailed example of the Discrete Prices Catalogues Scenario.....	25



# 1. Introduction

The European Commission (hereinafter “EC”) commissioned Axon Partners Group Consulting S.L.U. (hereinafter “Axon Consulting” or “Axon”) for the “Assessment of the cost of providing wholesale voice call termination services on fixed networks in the EU/EEA countries<sup>1</sup>” (‘the Project’).

As described during Workshop 1 held on 23 October 2018 at the EC’s premises<sup>2</sup>, the EC deemed relevant to develop a cost study to understand the costs of providing fixed termination voice services in EU/EEA countries. With such objective in mind, the EC/Axon team has developed a Bottom-Up Long Run Incremental Cost (hereinafter ‘BULRIC’) model that calculates the costs of providing wholesale voice call termination services on fixed networks in the EU/EEA countries.

This document constitutes the ‘descriptive manual’ of the cost model. Its main objectives are to:

- ▶ Describe the approach and structure followed in the development of the costing model.
- ▶ Describe the calculation processes and analyses performed in the model.
- ▶ Provide comprehensive descriptions of the calculation blocks of the model.

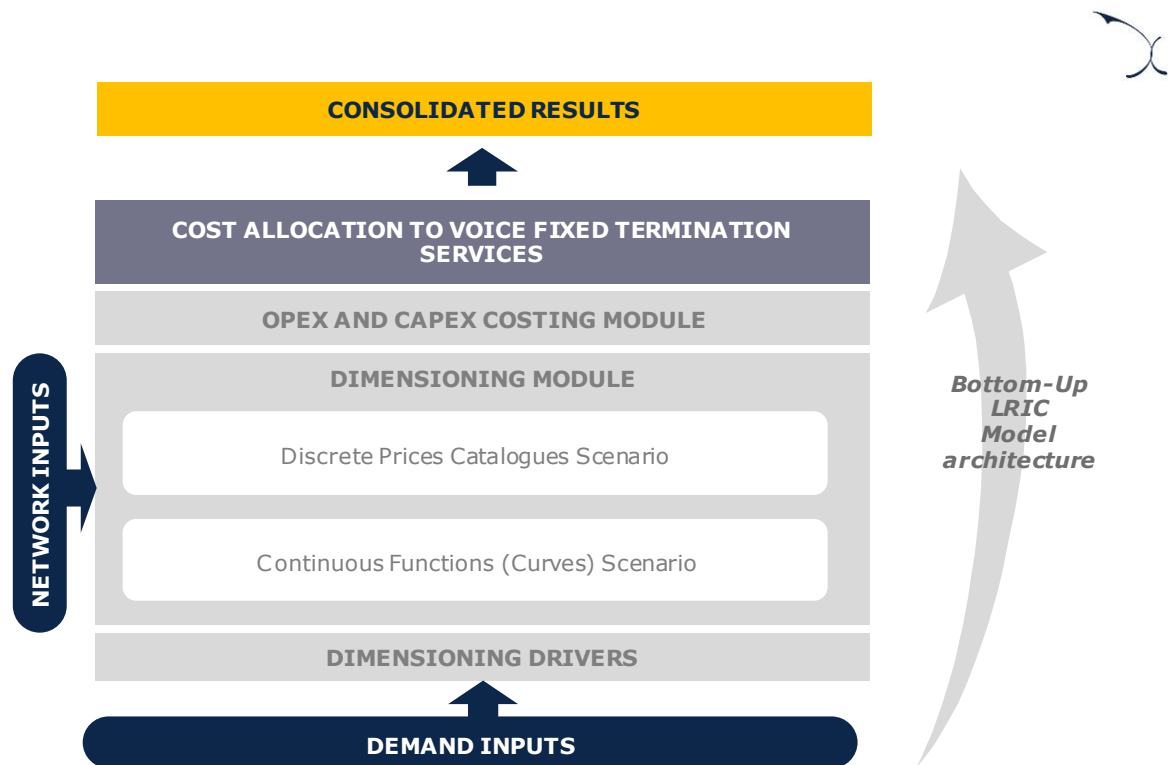
In particular, the model has been developed according to a Bottom-Up structure as graphically represented in the exhibit below:

---

<sup>1</sup> SMART 2018/0014

<sup>2</sup> A video version of the workshop is available at:

<https://webcast.ec.europa.eu/fixed-termination-rates-workshop-23-10-2018>



**Exhibit 1.1: Structure of the model [Source: Axon Consulting]**

As the exhibit above shows, the model is designed based on 4 key functioning blocks which are presented below:

- ▶ **Dimensioning Drivers (section 2):** Converts traffic into dimensioning drivers which help to perform the network dimensioning calculations.
- ▶ **Dimensioning Module (section 3):** Performs the dimensioning of the core network and calculates the configurations of platforms needed to supply the main services provided by the reference operator. The demand for all modelled services is used by the Dimensioning Module. Two different options are available for the dimensioning, based on either the Discrete Prices Catalogues Scenario or the Continuous Functions (Curves) Scenario.
- ▶ **OPEX and CAPEX costing module (section 4):** Calculates the costs of resources, both in terms of CapEx and OpEx. In addition, it includes the implementation of the economic depreciation mechanism to annualise capital investments over the years.
- ▶ **Cost allocation to voice fixed termination services (section 5):** Calculates the cost that must be allocated to voice fixed termination services, including incremental and wholesale specific costs.

The following sections further develop each block of the model.



## 2. Dimensioning Drivers

The rationale of the dimensioning drivers is to express traffic demand (at service level) in a way that facilitates the dimensioning of network resources.

The recognition of dimensioning "Drivers" is intended to simplify and increase the transparency of the network dimensioning process. Drivers enable the model to transform the demand of different services (which are measured in voice minutes or fixed telephony lines) into technical units which are relevant for the dimensioning process.

As such, the drivers defined in the cost model are listed below:

DRIVER	Unit
Demand handled by the AS	Subscribers
Demand handled by the CDF	CDR/hour
Demand handled by the I - CSCF	Subscribers
Demand handled by the S - CSCF	Subscribers
Demand handled by the Access SBC	Concurrent Sessions
Demand handled by the IX SBC	Concurrent Sessions
Demand handled by the ENUM	Subscribers
Demand handled by the MRF	Concurrent Voice Channels

**Exhibit 2.1: List of drivers used in the model (Sheet '0C PAR DRIVERS') [Source: Axon Consulting]**

The following steps are required to calculate the dimensioning drivers:

- ▶ Mapping services to drivers
- ▶ Converting traffic units into the driver units
- ▶ Calculation of dimensioning drivers

### 2.1. Mapping services to drivers

To calculate drivers' values, it is necessary to indicate what services are related to them. A service is generally assigned to more than one driver, as drivers represent traffic in a particular point of the network.

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

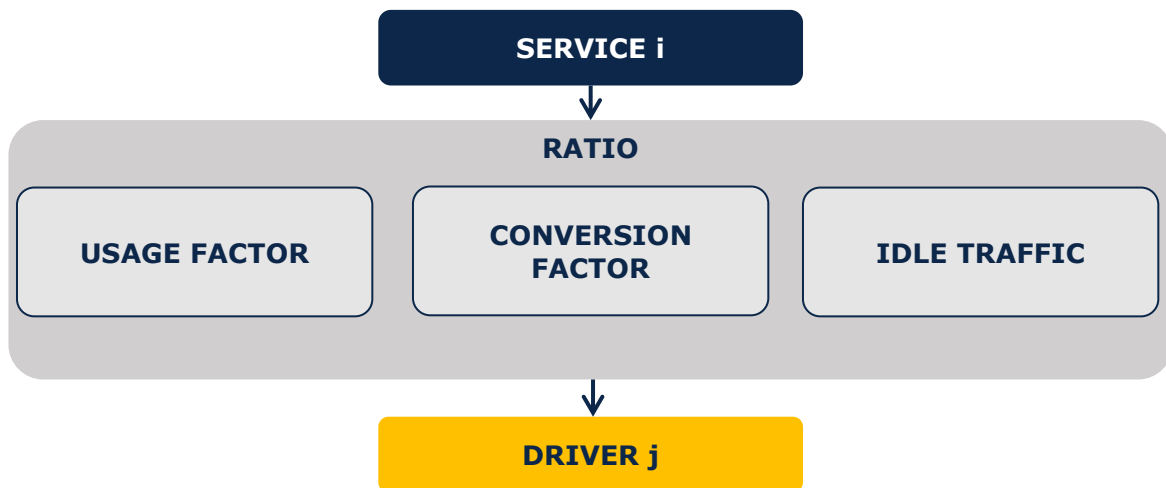


List of relationships	
SERVICE	DRIVER
Lines.Lines.Retail.Fixed Voice Lines	Demand handled by the AS
Voice.On Net.Retail.On-net	Demand handled by the CDF
Voice.Outgoing.Retail.Off-net to fixed national	Demand handled by the CDF
Voice.Outgoing.Retail.Off-net to mobile national	Demand handled by the CDF
Voice.Outgoing.Retail.Off-net international	Demand handled by the CDF
Voice.Incoming.Wholesale.Incoming from fixed national	Demand handled by the CDF
Voice.Incoming.Wholesale.Incoming from mobile national	Demand handled by the CDF
Voice.Incoming.Wholesale.Incoming from international	Demand handled by the CDF
Voice.Transit.Wholesale.Transit	Demand handled by the CDF
Voice.Other.Retail/Wholesale.Other voice traffic	Demand handled by the CDF

**Exhibit 2.2: Excerpt from the mapping between services and Drivers. (Sheet '3A MAP SERV2DRIV')**  
[Source: Axon Consulting]

## 2.2. Converting traffic units into the driver units

Once services have been mapped to drivers, volumes need to be converted to obtain drivers in the relevant units of measure. For this purpose, a ratio has been worked out representing the number of driver units generated by each service unit. In general, the calculation of this ratio consists of three factors, in accordance with the following structure:



**Exhibit 2.3: Units conversion process from services to drivers** [Source: Axon Consulting]

This ratio thus includes the following items:

- ▶ Usage factor (UF)
- ▶ Conversion Factor (CF)
- ▶ Idle Traffic (IT)





Unit conversation ratios are then obtained as per the following formula:

$$RATIO = UF \times CF \times (1 + IT)$$

- ▶ **Usage factor** represents the number of times a service makes use of a specific driver. For example, when calculating drivers related to the Access SBC<sup>3</sup> equipment, it is necessary to recognise that they will be used twice by on-net services. On the contrary, off-net and termination services will only use them once.
- ▶ **Conversion Factor** represents the relationship between services' units (e.g. minutes) to drivers' units (e.g. Concurrent Sessions).

For example, the conversion from voice minutes in the busy hour to Concurrent Sessions should be based on the following factor:

$$CF = \frac{1}{60}$$

Another example, the conversion from voice minutes in the busy hour to number of calls should be based on the following factor:

$$CF = \frac{1}{ACD \text{ (Average call duration)}}$$

- ▶ **Idle traffic** represents the difference between the traffic conveyed from the users' viewpoint and the required resource consumption the network needs to face. For instance, it recognises the traffic consumption generated by unanswered calls which, even though not invoiced, generate additional load to the network.

The calculation of the idle-traffic factor is based on the following elements:

- *Time required to set up the connection which is not considered as time of service.* It represents the waiting time until the recipient picks up the phone to accept the call. During this time an actual resource allocation is performed and, therefore, needs to be taken into consideration in the dimensioning of the network. Its calculation is performed as follows:

$$\text{Connection Time (\%)} = \frac{ART}{ACD}$$

Where:

- ART is the average ringing time.
- ACD is the average call duration.

---

<sup>3</sup> Session Border Controller. Please refer to section 3 for further details on network elements considered within the model.



- *Time required for missed calls*: This factor takes into consideration the time elapsed in trying to reach a recipient that does not answer the call. It is calculated as follows:

$$Uneffective\ time\ (\%) = \frac{\frac{PNRC}{1 - PNRC - PB} \cdot ART + \frac{PB}{1 - PNRC - PB} \cdot AT}{ACD}$$

Where:

- PNRC represents the percentage of non answered calls.
- PB is the percentage of calls where the recipient is busy.
- ART is the average ringing time.
- AT is the average duration of the message indicating the impossibility to contact the callee.
- ACD is the average call duration.

Finally, the total idle traffic is calculated as the sum of the time required to set up the connection and the time required for missed calls.

## 2.3. Calculation of dimensioning drivers

Once each relationship between services and drivers has been fully defined (in terms of mapping and conversion factors) the contribution from each service to the drivers can be added up as follows:

$$Driver_j = \sum_i Demand_i \cdot Ratio_{i,j}$$

When calculating the values of the final drivers to be used in the dimensioning module, an additional consideration is made:

- ▶ **Busy hour applicability**: The dimensioning of many of the network elements considered in the cost model is performed in the busy hour. Consequently, the yearly traffic needs to be multiplied by the percentage of traffic that is handled in the busy hour of an average day. The application of the busy hour percentage is performed in worksheet '4B CALC DRIVERS' of the model.

Not all drivers are measured in the busy hour. For instance, other network elements are dimensioned based on the total number of subscribers in the network rather than the number of subscribers making use of the network in the busy hour.



### 3. Dimensioning Module

The Dimensioning Module aims at dimensioning the core network resources required to serve the reference operator's demand. The following illustration shows the IMS network architecture considered in the model:

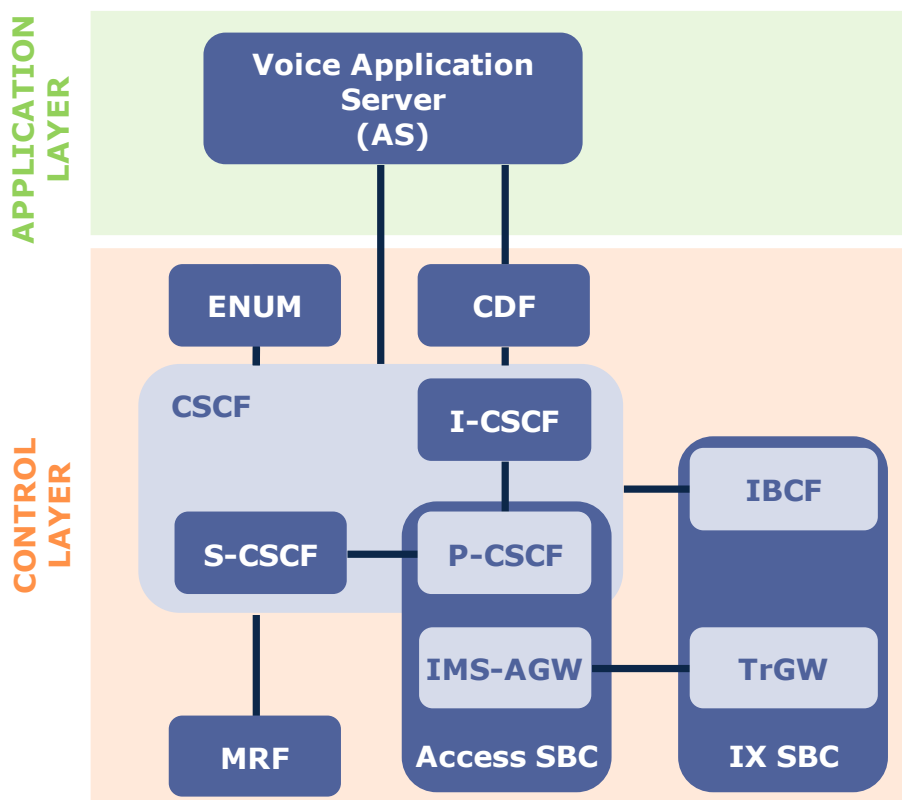


Exhibit 3.1: IMS network architecture considered in the model [Source: Axon Consulting]

A brief description of each of the core platforms is provided below:

- ▶ **AS (Application Server):** Provides voice and multimedia services over and above basic session setup. This terminology can be generally applied to different multimedia services. In the particular case of this study, focused on voice termination, the AS refers to a VoIP AS (e.g. SIP AS).
- ▶ **CDF (Charging Data Function):** Responsible for collecting and correlating chargeable event details for billing and charging purposes.
- ▶ **ENUM (Electronic Number Mapping System):** The ENUM is a platform that indirectly access different services available under a single personal identifier using the E.164 protocol.

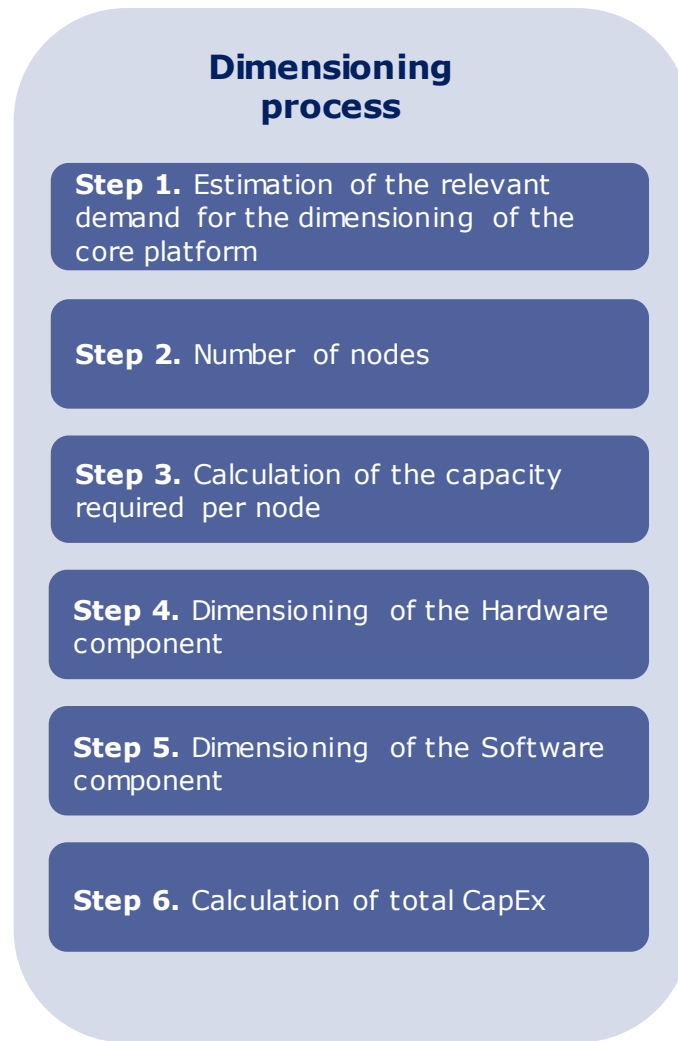


- ▶ **CSCF (Call Service Control Function):** The CSCF generally comprises three different network elements (although some manufacturers have integrated them in the same unit):
  - S-CSCF (Serving CSCF), responsible for directing signalling requests to Application Servers so as to invoke services for subscribers on the network.
  - I-CSCF (Interrogating CSCF), responsible for querying the HSS to obtain the identity of the S-CSCF to which signalling requests addressed to particular destination should be sent.
  - P-CSCF (Proxy CSCF), responsible for providing a secure edge between the access network and the IMS core network. In the model, this function is considered within the Access SBC.
- ▶ **SBC (Session Border Control) Functions:** Responsible for the session border control. Two different functions are typically differentiated:
  - Access SBC, which provides a secure edge between the access network and the IMS core network. It is typically composed of the P-CSCF (Proxy CSCF) which handles the signalling and the IMS-AGW (IMS Access Gateway) which handles the traffic.
  - Interconnection SBC, responsible for the interconnection with other NGN networks. It is typically composed of the IBCF (Interconnect Border Control Function), which handles the interconnection of signalling and the TrGW (Transition Gateway) which handles the interconnected traffic.

It is worth noting that in the model, both Access SBC and IX SBC core elements have been modelled without separating the signalling and traffic related parts. The reason is that information submitted by stakeholders regarding the Access SBC and the IX SBC showed that they were not generally able to separate the costs associated to the sub-functions.

- ▶ **MRF (Media Resource Function):** Provides media related functions such as media manipulation and playing of tones and announcements.

The dimensioning process for each of the core platforms considered in the model follows the same steps. These steps are shown in the following exhibit:



**Exhibit 3.2: Steps followed in the Dimensioning Module [Source: Axon Consulting]**

Algorithms implemented for these steps are included in worksheet '5A CALC DIM CORE' of the model. The detailed description of each step is provided in the following sections.

### **3.1. Step 1. Estimation of the relevant demand for the dimensioning of the core platform**

The first step required in the core network dimensioning process is the calculation of the demand that needs to be supported by the core platform under analysis. To this effect, each of the drivers listed in section 2 have been associated with one of the core platforms.



These drivers already reflect the total demand in the network that will have to be handled in each case<sup>4</sup>.

However, this demand is not considered as such in the dimensioning process, since it is necessary to first assume a maximum load factor of the core equipment. This factor is used for security purposes, to avoid network failures in case of a sudden peak in demand. Based on this, the capacity employed for the dimensioning of each core platform is calculated as follows:

$$\text{Capacity required} = \text{Demand} / \text{Maximum load of the core network}$$

### 3.2. Step 2. Number of nodes

The number of nodes related to each core platform is also necessary in the dimensioning process. This is an input of the model, which is based on the information provided by stakeholders and is included in worksheet '2B INP CORE NODES'. Step 2 basically consists of extracting, from the input table, the number of nodes related to the core platform under analysis.

### 3.3. Step 3. Calculation of the capacity required per node

The third step consists of calculating the capacity required for each core node. This calculation is performed firstly dividing the capacity estimated in Step 1 by the number of core nodes from Step 2, as follows:

$$\text{Capacity required per node} = \text{Capacity required} / \text{Number of nodes}$$

Once the capacity per node is estimated, two additional dimensioning factors are considered:

- ▶ **Redundancy factor:** A redundancy factor of two (2) is considered for security purposes. This implies that, in case of failure of one node, a closer node should be capable of handling both capacities (its own capacity and the capacity of the node that has failed).
- ▶ **Blocking probability (if applicable):** The blocking probability is used for voice services to recognize the implications in network dimensioning of ensuring a given

---

<sup>4</sup> Please note that the dominant driver for each core network element has been defined based on the feedback provided by stakeholders, as described in the document 'Annex 4 – Methodological approach document', section 3.1.5.



quality of service. For this purpose, it is necessary to apply the Erlang tables<sup>5</sup> to properly dimension the network under a given blocking probability. Note also that the blocking probability is not applied to all core network elements<sup>6</sup> (this is not applicable, for instance, in cases in which the dimensioning is based on the number of subscribers).

The application of these two parameters provides an adjusted value for the capacity required per node, which is employed in the dimensioning of the core platforms described in the following sections.

### **3.4. Step 4. Dimensioning of the Hardware component**

Two different scenarios are available in the model for the dimensioning of the hardware component of each core network element (see section 3.1.5 of document ‘Annex 4 – Methodological approach document’ for further detail about this topic), namely:

- ▶ Dimensioning based on the Discrete Prices Catalogues Scenario
- ▶ Dimensioning based on the Continuous Functions (Curves) Scenario

Following sections provide detailed explanations on these two approaches.

#### **3.4.1 Dimensioning based on the Discrete Prices Catalogues Scenario**

The dimensioning of the hardware component under the Discrete Prices Catalogues Scenario is described in this section. It is composed of the following steps:

- ▶ Calculation of potential configurations of platforms
- ▶ Selection of the optimal configuration of platforms

##### ***Calculation of potential configurations of platforms***

The first step consists of generating all the potential configurations of core platforms (candidates) that allow the reference operator to comply with its capacity requirements.

---

<sup>5</sup> The iterative formula of Erlang is implemented in the model by means of a Visual Basic code, which is accessible to stakeholders.

<sup>6</sup> The detail of elements to which the blocking probability is applied is located in worksheet ‘0C PAR DRIVERS’ of the cost model, see column ‘BLOCKING PROBABILITY DEPENDANT?’.



This calculation is performed by means of an algorithm incorporated in the model<sup>7</sup> that employs the following information:

- ▶ Capacity required per node calculated in Step 3
- ▶ Prices catalogues, consisting in data points reflecting the cost-capacity relationships associated to each network core element<sup>8</sup>

By following a number of steps, the algorithm generates all possible combinations of core platforms that allow the reference operator to comply with its capacity requirements. The following illustrative example shows the result of such algorithm:

<b>Requested Capacity: 4.300.000</b>		<b>Matrix of potential configurations of platforms</b>			
<b>Data points of the price catalogue</b>		<b>Config. 1</b>	<b>Config. 2</b>	<b>Config. 3</b>	<b>Config. 4</b>
<b>Core Equipment</b>	<b>Capacity</b>				
<b>Core Equipment 1</b>	5.000.000	1	-	-	-
<b>Core Equipment 2</b>	2.000.000	-	3	2	2
<b>Core Equipment 3</b>	1.000.000	-	-	1	-
<b>Core Equipment 4</b>	200.000	-	-	-	2

**Exhibit 3.3: Dimensioning based on the Prices Catalogues Scenario - Illustrative example of the matrix of potential configurations of platforms [Source: Axon Consulting]**

In the illustrative example above, four different configurations are identified to comply with the requested capacity of 4.300.000 units:

- ▶ One platform of the Core Equipment 1
- ▶ Three platforms of the Core Equipment 2
- ▶ Two platforms of the Core Equipment 2 + one platform of the Core Equipment 3
- ▶ Two platforms of the Core Equipment 2 + two platforms of the Core Equipment 4

Annex A provides the detail of the steps followed to generate the matrix of the above example.

### ***Selection of the optimal configuration of platforms***

The second step consists of selecting the combination of core platforms constituting the most cost-effective solution. In other words, it selects the cheapest combination of core platforms that allows the reference operator to comply with its capacity requirements.

<sup>7</sup> This algorithm is implemented in a Visual Basic Code, which is accessible by stakeholders.

<sup>8</sup> This information is included in worksheet '1D INP CORE PLATF UNITARY COSTS' of the model.





For that purpose, it multiplies the number of platforms obtained for each configuration, reflected in the matrix, by their unitary cost. The configuration whose total cost results in the cheapest solution is finally selected. This configuration is therefore the final output of the algorithm.

In our example, we assume the following illustrative unitary cost for the available core equipment:

Data points of the price catalogue	
Core Equipment	Unit Cost (EUR)
Core Equipment 1	280.000
Core Equipment 2	150.000
Core Equipment 3	100.000
Core Equipment 4	67.000

**Exhibit 3.4: Dimensioning based on the Prices Catalogues Scenario – Illustrative example of unitary cost of core equipment [Source: Axon Consulting]**

Therefore, the multiplication of the number of calculated platforms by these unitary costs produces the following results:

Data points of the price catalogue	Cost of the potential configurations of platforms (EUR)			
	Config. 1	Config. 2	Config. 3	Config. 4
Core Equipment 1	280.000	-	-	-
Core Equipment 2	-	450.000	300.000	300.000
Core Equipment 3	-	-	100.000	-
Core Equipment 4	-	-	-	134.000
<b>TOTAL COST</b>	<b>280.000</b>	<b>450.000</b>	<b>400.000</b>	<b>434.000</b>

**Exhibit 3.5: Dimensioning based on the Prices Catalogues Scenario – Illustrative example of total cost of core equipment [Source: Axon Consulting]**

The above results show that the Configuration 1, consisting of one platform of the Core Equipment 1 is the most cost-effective solution, and therefore, it is the one selected by the algorithm for each core node.

### 3.4.2 Dimensioning based on the Continuous Functions (Curves) Scenario

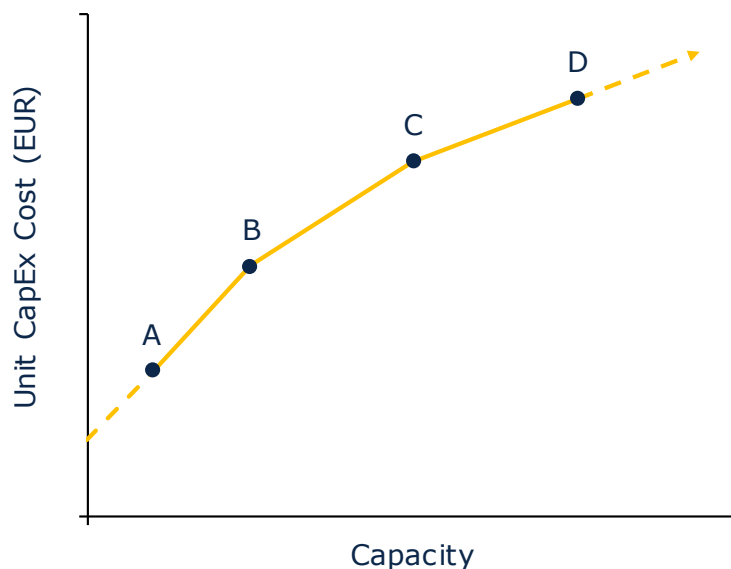
The dimensioning of the hardware component under the Continuous Functions (Curves) Scenario is described in this section. It is composed of the following steps:



- ▶ Calculation of the fixed points and slopes of the straight lines constituting the continuous function
- ▶ Calculation of the unit CapEx per node

**Calculation of the fixed points and slopes of the straight lines constituting the continuous function**

Instead of making use of discrete points such as the Prices Catalogue Scenario, the Continuous Function Scenario considers a continuity between the price-capacity data points, which consists in connecting each point (n) of the price catalogue with the next point (n+1) by means of a straight line. This is shown in the following illustrative example:



**Exhibit 3.6: Dimensioning based on the Continuous Function (Curve) Scenario - Illustrative example of a Continuous Function composed of several straight lines [Source: Axon Consulting]**

Each of the straight lines<sup>9</sup> connecting two points of the price catalogue presents the following linear equation:

$$y = Mx + N$$

Where:

- ▶ *M*: represents the slope of the straight line
- ▶ *N*: represents the fixed point (point of intersection with the vertical axis) of the straight line

<sup>9</sup> Please note that the scenario is also named as "Curve", given that the combination of all straight lines provides a continuous function which simulates a curve.



- ▶  $x$ : represents the independent variable (in this specific cost study it represents the capacity of the core platform)
- ▶  $y$ : represents the dependent variable (in this specific cost study it represents the CapEx cost of the core platform)

The slope of the straight lines is calculated based on the following equation:

$$\text{Slope } (M) = \frac{y_{n+1} - y_n}{x_{n+1} - x_n}$$

The fixed point of the straight lines (point of intersection with the vertical axis) is calculated based on the following equation:

$$\text{Fixed point } (N) = y_n - x_n \times \text{Slope } (M)$$

For example, in order to calculate the slope and fixed point of the straight-line connecting points B and C, the following equations are used:

$$\text{Slope}_{B-C} = \frac{\text{Capex}_C - \text{Capex}_B}{\text{Capacity}_C - \text{Capacity}_B}$$

$$\text{Fixed Point}_{B-C} = \text{Capex}_B - \text{Capacity}_B \times \text{Slope}_{B-C}$$

Additionally, it is also worth noting that, in order to define a continuous function from the beginning until the end of the horizontal axis (reserved for the capacity), the following assumptions are followed:

- ▶ The straight line connecting the two first points (in the chart above, it relates to points A and B) is extended until reaching the vertical axis.
- ▶ The straight line connecting the two last points (in the chart above, it relates to points C and D) is extended to infinity.

These two cases are represented in the chart by means of dashed lines.

### **Calculation of the unit CapEx per node**

Once the continuous function has been defined in the previous step, the cost associated to the required capacity for each core node is calculated.

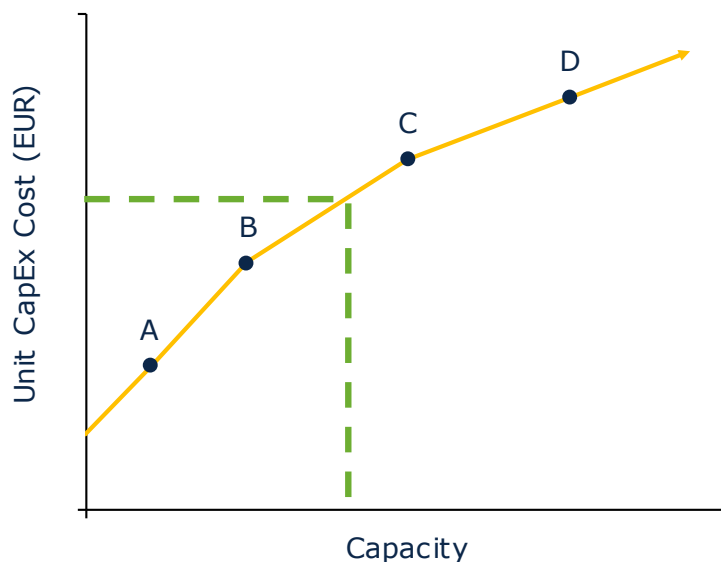
This calculation is performed in the model making use of the following information:

- ▶ Capacity required per node calculated in Step 3



- ▶ Continuous function, defined by the straight lines calculated in the paragraphs above

The following exhibit provides an illustrative example of the calculation performed in the model:



**Exhibit 3.7: Dimensioning based on the Continuous Function (Curve) Scenario - Illustrative example of the calculation of the unit CapEx per node [Source: Axon Consulting]**

The model takes as starting point the capacity per node calculated in Step 3. This capacity must be supported by the core platform that will be selected by the model. Thus, the point of intersection of such capacity with the continuous function provides the unit CapEx of the required core platform in each node.

### **3.5. Step 5. Dimensioning of the Software component**

The same process performed for the Hardware component, which has been described in Step 4, is performed for the Software component.

### **3.6. Step 6. Calculation of total CapEx**

The final step consists of estimating the total CapEx (total acquisition cost) associated to the core network element under analysis, and considering all nodes. This calculation is performed multiplying the CapEx cost per node estimated in step 4 for the hardware component and in step 5 for the software component, by the number of core nodes from Step 2, as follows:

$$\text{Total CapEx} = \text{CapEx per node} \times \text{Number of core nodes}$$



The use of the CapEx cost per node from Steps 4 and 5 may refer to the output of the dimensioning process based either on the Prices Catalogues Scenario or on the Continuous Functions (Curves) Scenario. The selection between both options is made by the model considering the `Core Platforms Dimensioning scenario` selected by the user in the `COVER` worksheet of the model.



## 4. OPEX and CAPEX costing module

The purpose of the OpEx & CapEx costing module is to calculate the annual expenditures (OpEx and CapEx) associated with the required network core resources calculated in the dimensioning module. This section is divided in the following sub-sections:

- ▶ Definition of unitary costs and trends
- ▶ OpEx
- ▶ CapEx

### 4.1. Definition of unitary costs and trends

The calculation of the cost associated to the network relies on the number of core network elements (calculated through the procedures described in section 3) and the unitary costs and trends of the core resources (defined in worksheet '1D INP CORE PLATF UNITARY COSTS' of the model). For further indications on how unit costs and trends are defined in the cost model, please refer to the methodological approach document.

Based on these inputs, the model calculates in worksheet '4A CALC PLAT UNITARY COSTS' the Unitary CAPEX for each of the years defined in the cost model.

### 4.2. OpEx

OpEx is calculated in the model by means of a percentage over the equipment acquisition price (% of OpEx over CapEx) for that particular year.

This calculation is performed in the model in worksheet '6A CALC RES OPEX', multiplying the Total CapEx of the core resources (calculated in worksheet '5A CALC DIM CORE') and the OpEx percentage inputs (defined in worksheet '1D INP CORE PLATF UNITARY COSTS').

This calculation is performed for each of the increments defined. More specifically, in worksheet '6A CALC RES OPEX', tables on the left (named as 'Total Cost') calculate the cost of the core network that must support the demand of all services, while tables on the right (named as 'Termination') calculate the cost of the core network that must support the demand of services after removing the voice termination increment.



### 4.3. CapEx

While core network OpEx is calculated in a straightforward manner, the calculation of the annualised capital expenses requires the implementation of a cost depreciation methodology.

As described in the methodological approach document, an economic depreciation mechanism has been implemented.

According to Hicks' classical approach<sup>10</sup>, economic depreciation is the cost of maintaining the value of capital stock (that is, the level of wealth) constant between several periods. More generally, economic depreciation is defined as the difference between the period to period variation of the market value of an asset.

Economic depreciation has been implemented in the cost model based on the following formula:

$$d_i = O_i p_i \frac{\sum_{j=1}^N \alpha_j I_j}{\sum_{j=1}^N \alpha_j O_j p_j}$$

Where,

- ▶  $d_i$  represents the annual depreciation cost
- ▶  $O_i$  is the production factor of the asset, defined based on the demand that the asset is expected to serve
- ▶  $p_i$  is the reference price of the asset in year  $i$
- ▶  $\alpha_j$  represents the cost of capital dividing term and is calculated as  $(1+WACC)^j$  where  $j$  is the relevant year (in terms of 1, 2, 3, 4, etc.)
- ▶  $I_j$  represents the yearly investment, calculated as the number of assets purchased in year  $j$  multiplied by their unit price in that year
- ▶  $N$  represents the last year in which an asset is used in the network

Equivalently to the approach indicated for OpEx, this calculation is also performed for each of the increments defined. More specifically, in worksheet '6B CALC RES CAPEX', tables on the left (named as 'Total Cost') calculate the cost of the core network that must support the demand of all services, while tables on the right (named as 'Termination') calculate

---

<sup>10</sup> "Value and Capital: An Inquiry Into Some Fundamental Principles of Economic Theory", 1939.



the cost of the core network that must support the demand of services after removing the voice termination increment.





## 5. Cost allocation to voice fixed termination services

This section describes the approach adopted in the model to calculate the costs of the reference operator modelled and how they are allocated to voice fixed termination services under the Pure LRIC standard.

This section is split according to the 2 cost categories that have been considered in the model:

- ▶ Incremental costs
- ▶ Wholesale specific costs

### 5.1. Incremental costs

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

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

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

To calculate incremental costs, increments are defined as groups of services.

In the particular case of this cost study, only one increment that gathers the three relevant services of voice fixed termination is needed. These services are:

- ▶ Voice.Incoming.Wholesale.Incoming from fixed national
- ▶ Voice.Incoming.Wholesale.Incoming from mobile national
- ▶ Voice.Incoming.Wholesale.Incoming from international



Therefore, these services have to be assigned to the termination increment in worksheet '0A PAR SERVICES'.

In the model, resources' incremental costs are calculated as follows:

- ▶ In the case of **core network elements**, these costs are calculated in worksheets '6A CALC RES OPEX' and '6B CALC RES CAPEX'.
- ▶ In the case of **active transmission and switching equipment**, these costs are calculated in worksheet '6C CALC RES ACTIVE EQUIP COST'. The calculation is based on a mark-up applied over the incremental costs of the core network elements (from previous point). Further details about the definition and the consideration of this mark-up are provided in the methodological approach document.

## 5.2. Wholesale specific costs

Wholesale specific costs relate to the expenses generated by fixed operators for the provision of voice termination services.

The methodological approach document includes detailed indication on the wholesale cost categories considered and how they have been defined in the model.

The calculation of wholesale specific costs is performed in the model in worksheet '6D CALC SERVICE SPEC COSTS'.



## Annex A. Detailed example of the Discrete Prices Catalogues Scenario

This Annex describes the steps that are followed by the model, under the Discrete Prices Catalogues Scenario, in order to generate the following illustrative example of matrix of potential configurations of platforms:

Requested Capacity: 4.300.000		Matrix of potential configurations of platforms			
Data points of the price catalogue		Config. 1	Config. 2	Config. 3	Config. 4
Core Equipment	Capacity				
Core Equipment 1	5.000.000	1	-	-	-
Core Equipment 2	2.000.000	-	3	2	2
Core Equipment 3	1.000.000	-	-	1	-
Core Equipment 4	200.000	-	-	-	2

**Exhibit 5.1: Dimensioning based on the Prices Catalogues Scenario - Illustrative example of the matrix of potential configurations of platforms [Source: Axon Consulting]**

Steps followed by the algorithm to fill in the matrix are as follows:

1. The algorithm takes as starting point the capacity per node calculated in Step 3 (see section 3.3). This capacity must be supported by the combination of core platforms that will be selected. In our illustrative example, this capacity is 4.300.000 units.
2. Considering the required capacity, the algorithm identifies, within the price catalogue, what are the data points with a capacity immediately above and below<sup>11</sup>. In this respect, it is important to note that capacities of the price catalogue are introduced in the model in order, from the highest to the lowest. In our example, the data point with a capacity immediately above is the Core Equipment 1 (with 5.000.000 capacity units) and the data point with a capacity immediately below is the Core Equipment 2 (with 2.000.000 capacity units).
3. It is clear that one unit of the platform with a capacity immediately above is already enough to comply with the requested capacity. Based on this, the algorithm stores a value of 1 in the cell located in the diagonal of the matrix corresponding to the data point with a capacity immediately above (in our example, Core Equipment 1). This is illustrated below:

<sup>11</sup> In the event that, when looking at the price catalogue, no capacity above is available, the sub-step 3 described below is not necessary, and as such, it will be skipped by the algorithm. By contrast, if no capacity below is available, sub-steps 4 and 5 described below will be skipped by the algorithm.



Requested Capacity: 4.300.000		Matrix of potential configurations of platforms			
Data points of the price catalogue		Config. 1	Config. 2	Config. 3	Config. 4
Core Equipment	Capacity				
Core Equipment 1	5.000.000	1	-	-	-
Core Equipment 2	2.000.000	-	-	-	-
Core Equipment 3	1.000.000	-	-	-	-
Core Equipment 4	200.000	-	-	-	-

**Exhibit 5.2: Dimensioning based on the Prices Catalogues Scenario – Illustrative example of sub-step 3 [Source: Axon Consulting]**

4. In an equivalent manner, for the capacity immediately below, the algorithm calculates how many units of this platform are needed to comply with the requested capacity. In particular, this calculation is made by dividing the requested capacity between the capacity of the data point which is immediately below, and rounding it up. In our example, this data point is the Core Equipment 2 and the result of the calculation is 3 platforms (round up of  $4.300.000/2.000.000$ ). Then, the algorithm stores this result in the cell located in the diagonal of the matrix corresponding to the data point with a capacity immediately below. This is illustrated below:

Requested Capacity: 4.300.000		Matrix of potential configurations of platforms			
Data points of the price catalogue		Config. 1	Config. 2	Config. 3	Config. 4
Core Equipment	Capacity				
Core Equipment 1	5.000.000	1	-	-	-
Core Equipment 2	2.000.000	-	3	-	-
Core Equipment 3	1.000.000	-	-	-	-
Core Equipment 4	200.000	-	-	-	-

**Exhibit 5.3: Dimensioning based on the Prices Catalogues Scenario – Illustrative example of sub-step 4 [Source: Axon Consulting]**

5. Sub-steps 3 and 4 have already generated the two first configurations of core platforms that allow the reference operator to comply with the requested capacity. They have been stored in the two first columns. However, there may exist other combinations of core platforms which are also valid and could result in lower investment requirements. In particular, rounding up the number of platforms estimated in sub-step 4 may be introducing an unnecessary overcapacity. To put it another way, instead of rounding up, another alternative would be rounding down (therefore, installing one unit less of the platform which had a capacity immediately below the requested capacity) and to assess if the missing capacity may be supplied by a combination of platforms with lower capacities. Before assessing combinations of platforms allowing this, the algorithm stores the configuration right below the required capacity. This is illustrated below:



Requested Capacity: 4.300.000		Matrix of potential configurations of platforms			
Data points of the price catalogue		Config. 1	Config. 2	Config. 3	Config. 4
Core Equipment	Capacity				
Core Equipment 1	5.000.000	1	-	-	-
Core Equipment 2	2.000.000	-	3	2	2
Core Equipment 3	1.000.000	-	-	-	-
Core Equipment 4	200.000	-	-	-	-

**Exhibit 5.4: Dimensioning based on the Prices Catalogues Scenario – Illustrative example of sub-step 5 [Source: Axon Consulting]**

- The unsatisfied capacity is calculated as the difference between i) the requested capacity and ii) the capacity of the configuration selected in step 5 above. In the illustrative example i) is 4.300.000 capacity units and ii) is 2.000.000 x 2 = 4.000.000 capacity units). Therefore, there are 300.000 capacity units to be satisfied with lower configurations.
- The algorithm repeats sub-steps from 2 to 6, considering the unsatisfied capacity as the new requested capacity. In our example, the new requested capacity is 300.000 units, the data point with a capacity immediately above is now the Core Equipment 3 (with 1.000.000 capacity units) and the data point with a capacity immediately below is now the Core Equipment 4 (with 200.000 capacity units). The outcomes of repeating this process are illustrated below:

New Requested Capacity: 300.000		Matrix of potential configurations of platforms			
Data points of the price catalogue		Config. 1	Config. 2	Config. 3	Config. 4
Core Equipment	Capacity				
Core Equipment 1	5.000.000	1	-	-	-
Core Equipment 2	2.000.000	-	3	2	2
Core Equipment 3	1.000.000	-	-	1	-
Core Equipment 4	200.000	-	-	-	2

**Exhibit 5.5: Dimensioning based on the Prices Catalogues Scenario – Illustrative example of sub-step 7 [Source: Axon Consulting]**

The same process is repeated as many times as necessary, until the end of the price catalogues is reached.