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Excellence in Business

Cost of Providing Roaming Wholesale Services – CNECT/2022/OP/0065

Methodological Approach Document

Axon Partners Group

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Contents

1. Introduction

The European Commission (hereinafter "EC") commissioned Axon Partners Group Consulting S.L.U. (hereinafter "Axon Consulting" or "Axon") for the realization of the study "*Cost of Providing Roaming Wholesale Services – CNECT/2022/OP/0065* ('the Project').

As described during the Workshop 1, held on 21 June 2023, the EC deemed relevant to develop a new cost study to understand the costs of providing mobile services in EU/EEA countries. This initiative was necessitated by the new roaming regulation ('the Regulation')[1], which requires comprehensive review reports in the years 2025 and 2029. As part of this cost study, the Axon/EC team has updated the Bottom-Up cost model previously elaborated by the EC/Axon during the project SMART 2017/0091[2], which calculates the costs of providing mobile services in the EU/EEA countries. The updated model aligns with the current market conditions and adheres to the regulatory framework established by the Regulation, ensuring that the EC's approach is both current and compliant for the forthcoming review periods.

The objective of this document is to describe the methodological approaches adopted in the update of the model as well as to present the procedures followed by the Axon/EC team to define the model's inputs.

This document includes:

- An overview of the main methodological approaches adopted in the cost model (section 2).
- A description of the key inputs considered in the implementation of the model, describing how they were produced based on the data reported by NRAs (section 3).
- A description of the new elements added in the model's update with respect to the previous model's version from SMART 2017/0091 (section 4).

[1] Regulation (EU) 2022/612 of the European Parliament and of the Council of 6 April 2022 on roaming on public mobile communications networks within the Union.

[2] The complete list of public materials developed as part of such project is available in the following link: https://digital-strategy.ec.europa.eu/en/library/finalisation-mobile-cost-model-roaming-and-delegated-act-single-eu-wide-mobile-voice-call

- An introduction to the main outputs produced by the model, including the approach adopted to assess the reconciliation of sites and cost base of the modelled operator to the realities of MNOs in each country (section 5).
- A description of the process defined for future model's updates (section 6)
- An overview of the approach followed by the EC to estimate transit charges (section 7).

2. Methodological approach

The Commission Recommendation of 7 May 2009 on the "*Regulatory Treatment of Fixed and Mobile Termination Rates in the EU*"[3] defined the key methodological guidelines to be observed by European NRAs in the determination of fixed and mobile termination rates.

The guidelines presented in this recommendation were adopted by the EC in the development of the first cost study to assess the costs of providing mobile roaming services in the EU/EEA (SMART 2015/0006).

The methodological choices presented in the 2009 Recommendation were reinforced in the European Electronic Communications Code (EECC)[4].

The approach used in the previous SMART 2017/0091 was consistent with the methodological guidelines adopted in the SMART 2015/0006 cost study, as well as with the 2009 Recommendation and the related provisions in the EECC. These methodological principles also remain valid for the new project CNECT/2022/OP/0065.

The table below provides a summary of the key methodological approaches adopted in the cost model:

[3] Source: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:124:0067:0074:EN:PDF

[4] Source: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L:2018:321:FULL. Annex III "*Criteria for the determination of wholesale voice termination rates*" includes the relevant methodological indications about the calculation of mobile voice termination costs.

Methodological aspect	Approach Adopted
Cost standard	▶ Pure LRIC (termination) and LRIC+ (rest).
Cost categories considered	▶ Network CapEx. ▶ Network OpEx. ▶ General and administration costs (G&A). ▶ Wholesale specific costs
Modelled operator	▶ Hypothetical Efficient operator, with a market share equal to 1/#MNOs (subject to a minimum of 20%).
Depreciation methodology	▶ Economic depreciation
Modelled period	▶ 2022-2032

Table 2.1: Summary of the main methodological approaches adopted in the development of the cost model [Source: Axon Consulting]

Additionally, the table below describes at a high level the methodological treatment given to other relevant elements of the cost model:

Methodological aspect	Approach Adopted	Section
Volume forecasts	▶ Roaming traffic projections are based on an assessment of roamers' usage patterns. ▶ The busy hour input takes into account the different patterns exhibited by roaming services (when data was provided). ▶ A total of three scenarios are included to assess volume forecasts (conservative, base case and aggressive) to assess their relevance and impact on the results.	3.1.2

Methodological aspect	Approach Adopted	Section
Allocation of joint and common costs	▶ Two cost allocation modules are available in the model: • *Network module*: Joint and common costs are allocated to services based on their network usage, by using a routing factors matrix. • *Regulatory policy module*: The allocations performed in the network module are adjusted to take into account regulatory policy decisions (e.g. re-allocation of the joint and common costs initially allocated to the voice/SMS termination service to voice/SMS origination). Please refer to the descriptive manual for further indications on how this was implemented.	N/A
Economic depreciation	▶ The implementation of economic depreciation is performed at asset level. ▶ Two economic depreciation scenarios are included, based on (i) demand or (ii) revenues, as the relevant production factors.	2.1
Seasonality	▶ The impact of seasonality was assessed (when data was available). ▶ Three scenarios are available to assess the impact of considering different thresholds to identify the existence of seasonality (10%, 30% and 50%).	3.1.10
Unit Costs	▶ The model considers country-specific unit costs for access network assets and spectrum, while it adopts EEA averages for the remaining network assets.	3.1.6
Single-RAN	▶ A full Single-RAN deployment scenario is considered.	N/A

Methodological aspect	Approach Adopted	Section
Spectrum	▶ Spectrum license costs are country-specific and reflect the costs faced by MNOs. The useful life of spectrum licenses is country-specific too. ▶ The amount of MHz per spectrum band is defined to properly reflect the spectrum available in each country. ▶ The amount of spectrum available and its split per access technology varies over time.	3.1.6

Table 2.2: Main methodological aspects and approaches adopted in the model [Source: Axon Consulting]

The subsections below describe the different scenarios defined in the cost model:

- Economic depreciation
- Definition of increments under a LRIC cost standard
- Allocation of wholesale specific costs
- Traffic patterns and seasonal behaviours
- Domestic data demand forecasts
- Allocation of common costs based on traffic or customers

2.1. Economic depreciation

According to Hicks' classical approach[5], economic depreciation refers to 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 was 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
- p_i is the reference price of the asset in year i
- α_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

Two alternative production factors are included in the model to assess the results produced by the economic depreciation, namely:

- *Revenues*: It depreciates assets' costs based on the revenues they are expected to generate.
- *Demand*: It depreciates assets' costs based on the demand they are expected to serve.

The results obtained under each scenario can be assessed by selecting the desired option in the control panel of the model (please refer to the 'User manual' for further indications on how to run the model):

[5] "*Value and Capital: An Inquiry Into Some Fundamental Principles of Economic Theory*", 1939.

Exhibit 2.1: Selection of the alternative production factors to calculate the economic depreciation [Source: Axon Consulting]

2.2. Definition of increments under a LRIC cost standard

A LRIC increment is defined as a (group of) service(s) that is (are) treated as a single unit when assessing their incremental cost. Given that incremental costs are calculated as the cost savings from ceasing the production of an increment (be it a service or group of services), the definition of the increment(s) has a direct impact on the results that will be produced by the cost model.

Therefore, in the implementation of a LRIC cost model it is essential to introduce a formal definition of the increments to be considered.

The EC's recommendation on the "*Regulatory Treatment of Fixed and Mobile Termination Rates in the EU*" is clear in suggesting the definition of a single increment for voice termination:

> "*It is justified to apply a pure LRIC approach whereby the relevant increment is the wholesale call termination service and which includes only avoidable costs*"

However, no further indications are provided in any official documents on the approach to be adopted in the definition of the increment(s) applicable to other services that are particularly relevant in the case of wholesale roaming.

In light of this, two alternative definitions of the increments were included in the model:

- *Specific roaming increment*: This option considers three increments:
  - Termination: includes the traffic from the voice termination service only
  - Domestic: includes the traffic from all domestic services except for voice termination
  - Roaming: includes the traffic from all roaming services

  This approach aims at maximising consistency with the EC's 2009 Recommendation with regards to termination rates, as it assesses the incremental costs of the regulated service (mobile voice call termination) separately, and to similarly treat the mobile roaming increment separately from other non-regulated domestic services, although recognising that roaming services should also contribute to the recovery of joint and common costs.
- *Joint roaming and domestic increment*: This option considers two increments:
  - Termination: includes the traffic from the voice termination service only
  - Other: includes the traffic from all remaining services (inc. domestic and roaming)

This approach aims at maximising consistency in the determination of domestic and roaming services' costs.

The results obtained under each scenario can be assessed by selecting the desired option in the control panel of the model (please refer to the 'User manual' for further indications on how to run the model):

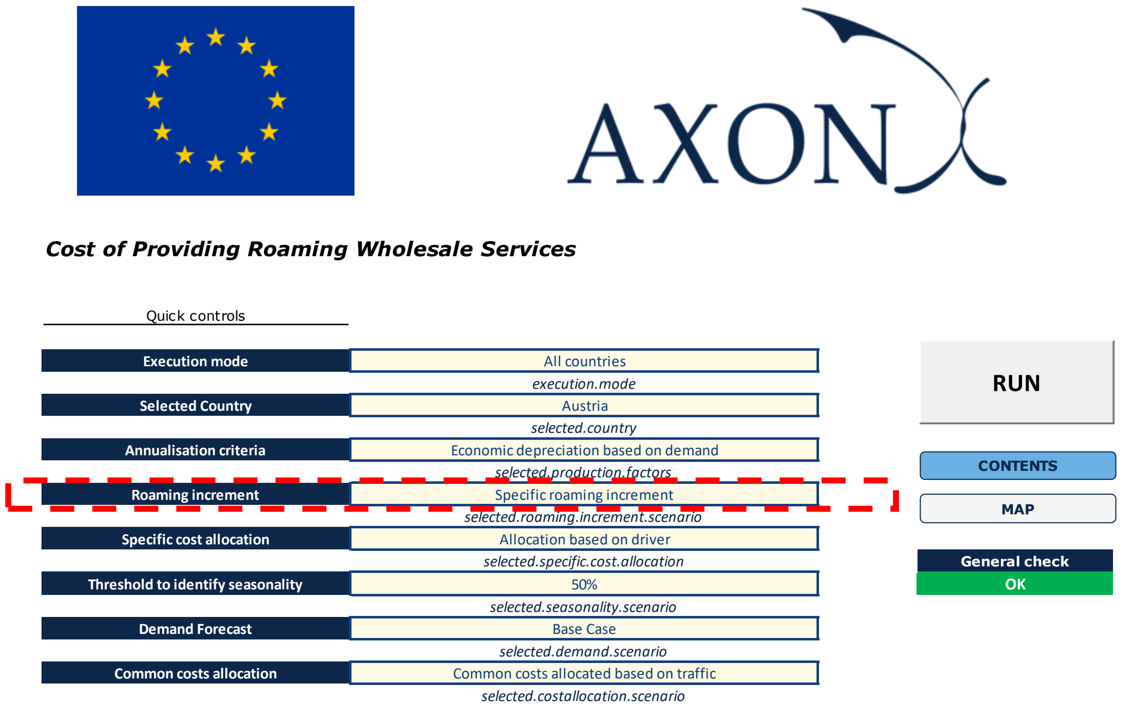

Exhibit 2.2: Selection of the increments to be considered in the model [Source: Axon Consulting]

2.3. Allocation of wholesale specific costs

Wholesale specific costs refer to the costs incurred by an MNO to provide wholesale services to third parties. As described in the Data Request Form, these include:

- Route testing/monitoring and opening costs
- Operation and maintenance (O&M) costs
- Data clearing costs
- Financial clearing costs
- Negotiation and contract management/regulation costs

Section 3.1.14 provides further indications on how these costs were calculated and introduced in the cost model.

These wholesale costs are allocated across both domestic and roaming services, namely:

- Data services:
  - Roaming – Inbound data (within EU/EEA and outside EU/EEA)
  - Roaming – Outbound data (within EU/EEA and outside EU/EEA)
- Voice services:
  - Domestic – Voice off-net to national
  - Domestic – Voice off-net to international
  - Domestic – Voice incoming from national
  - Domestic – Voice incoming from international
  - Roaming – Voice outbound - outgoing (within EU/EEA and outside EU/EEA)
  - Roaming – Voice outbound – incoming (within EU/EEA and outside EU/EEA)
  - Roaming – Voice inbound - outgoing (within EU/EEA and outside EU/EEA)
  - Roaming – Voice inbound – incoming (within EU/EEA and outside EU/EEA)
- SMS services:
  - Domestic – SMS off-net to national
  - Domestic – SMS off-net to international
  - Domestic – SMS incoming from national
  - Domestic – SMS incoming from international

- Roaming – SMS outbound - outgoing (within EU/EEA and outside EU/EEA)
- Roaming – SMS outbound – incoming (within EU/EEA and outside EU/EEA)
- Roaming – SMS inbound - outgoing (within EU/EEA and outside EU/EEA)
- Roaming – SMS inbound – incoming (within EU/EEA and outside EU/EEA)

In order to perform this cost allocation, two different allocation criteria are available in the model:

- *Allocation based on the drivers used in the regression analysis*: Cost allocation is performed based on the drivers (GB or TAPs) defined for each cost category to build up the regressions described in section 3.1.13.
- *Allocation based on GB*: Cost allocation for each cost category is performed based on the equivalent number of GB generated by each service. The conversion factors considered are also described in section 3.1.13.

The results obtained under each scenario can be assessed by selecting the desired option in the control panel of the model (please refer to the 'User manual' for further indications on how to run the model):

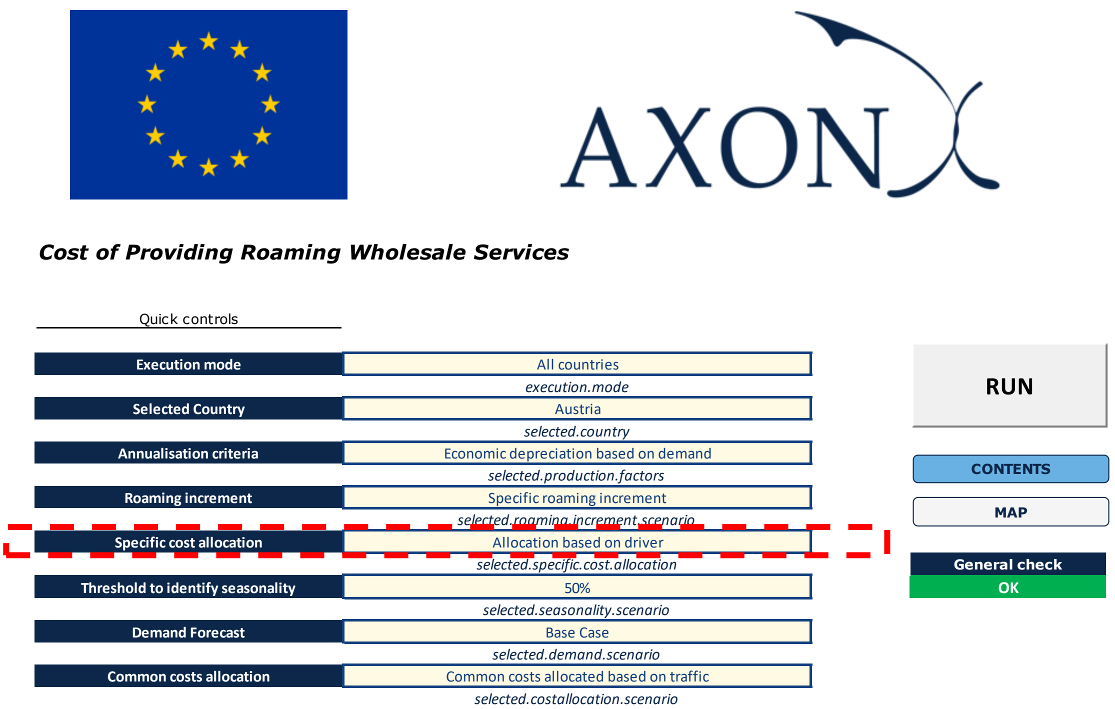

Exhibit 2.3: Selection of the alternative wholesale cost allocation options in the model [Source: Axon Consulting]

2.4. Traffic patterns and seasonal behaviours

Typically, traffic is not equally distributed across all months of a year but tends to fluctuate over time. Therefore, in order to design a network that is capable of accommodating the capacity requirements at different points in time, it is preferable to understand how traffic patterns may vary over the course of the year.

If traffic patterns in the cost model are assessed on an annual basis, an implicit assumption is made that all annual traffic is equally distributed across the year. Under this scenario, the percentage of traffic handled in the busy day of the year is typically calculated as follows:

$$Traffic_{BH} = \frac{YearlyTraffic}{365} \cdot \%\, Traffic_{BH_{day}}$$

That is, the traffic handled in the busy hour of an average day is calculated as the total traffic in the year divided by 365 (number of days in a year) and multiplied by the percentage of traffic served in the busy hour of the day.

However, as the following Exhibit 2.4 illustrates, this approach is not representative of the more realistic situation experienced by mobile networks in most EEA countries:

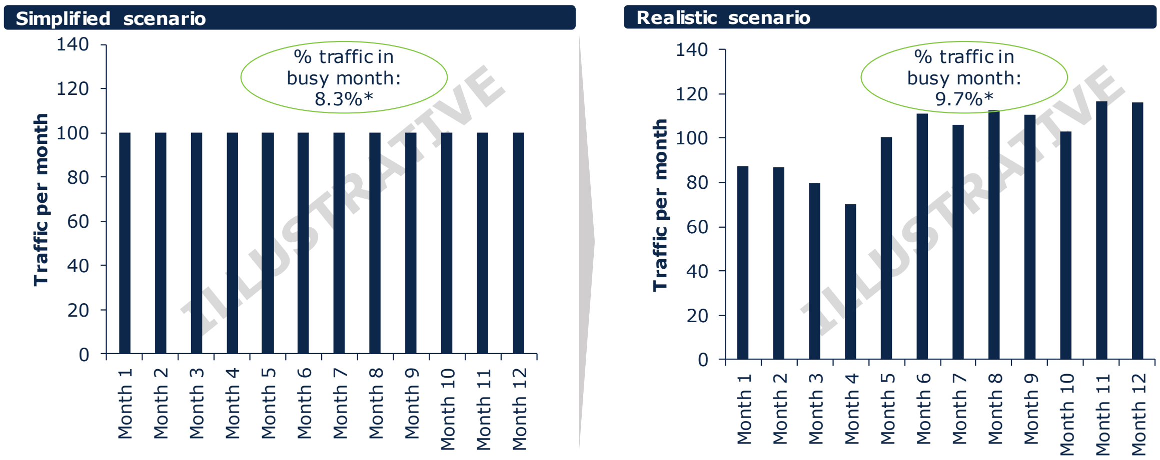

Exhibit 2.4: Comparison between a simplified and a more realistic (albeit dummy) traffic distribution scenario [Source: Axon Consulting]. Note: The percentage of traffic in the busy month presented in the two scenarios has been calculated as the traffic in the busy month divided by total traffic in the year.

Therefore, to accurately reflect the traffic load that the network is expected to serve, it is preferable to assess the network's traffic distribution on a monthly basis (rather than using annual traffic data and assume constant monthly traffic).

In the Data Request Form, we requested operators to provide traffic splits per site and month for the purpose of assessing seasonality of traffic throughout the year and its potential impact on underlying costs. We assessed seasonality and its impact on network costs for the countries that provided the information necessary for this analysis in their replies to our information requests. A detailed description of this analysis is presented in Section 3.1.10.

Additionally, the assessment of traffic seasonality showed that this traffic pattern may have differing relevance depending on the network's geographic location. For example, there may be specific geographic locations in which traffic seasonality is less pronounced and, conversely, other geographic locations (e.g. areas with greater influx of seasonal roaming or domestic end-users) may experience much greater traffic seasonality. While the seasonal behaviour itself would already be partially captured in the calculation of the percentage of traffic in the busiest month, an appropriate recognition of such situation merited a more granular geographic disaggregation to avoid mixing municipalities in different geographic locations with quite different characteristics in terms of their traffic patterns over the course of the year. In other words, if municipalities with different seasonal traffic patterns were modelled together, particularly in the case of municipalities with opposing seasonal traffic, the impact of seasonality on network dimensioning would be blurred, hence leading to a likely underestimation of the network requirements. In order to implement this more granular geographic analysis of traffic seasonality, we introduced new geotypes in the cost model[6].

The table below provides an illustrative example that highlights the relevance of considering disaggregated geotypes when diverging seasonal patterns are detected in different geographic locations:

[6] Refer to section 3.1.14 for a detailed description of geotypes and the overall geographical analysis performed.

KPI	Geotype A - seasonal (1)	Geotype A – not seasonal (2)	Geotype A (1+2)	Geotype A (assessed without seasonal disaggregation)
Total yearly traffic (A)	10,000	10,000	20,000	20,000
% of traffic in the busy month (B)	11.0%	8.5%	10.25%	10.25%
% of traffic in the busy hour of a day (C)	6.0%	6.0%	6.0%	6.0%
Traffic in busy hour (D=AxBxC/30)	2.2	1.7	3.9	3.9
Capacity of a site (E)	2	2	2	2
Sites required (D/E)	**2**	**1**	**3 (1+2)**	**2**

Table 2.3: Illustrative overview of the potential undesired effects of an inappropriate definition of geotypes when seasonal behaviours are detected [Source: Axon Consulting]

The table above presents the case of (i) a municipality with seasonal traffic (Geotype A - seasonal), in which a greater share of the total annual traffic (11% of total annual traffic) concentrates in the busy month; and (ii) a municipality with a more constant monthly traffic (Geotype A – not seasonal), in which a relatively lower share of total annual traffic (8% of total annual traffic) concentrates in the busy month. As the table above shows, when groups of municipalities (geotypes) with different seasonal behaviours are mixed together in a single geotype ('Geotype A (assessed without seasonal disaggregation)' column in the table above), the results of the model may underestimate the actual network requirements. In this example, the number of sites dimensioned when a single geotype is considered (2 sites) is below the figure obtained by dimensioning them separately ('Geotype A (1+2)' column, requiring 3 sites).

The main steps performed in the cost model in order to assess the impact of seasonal traffic patterns on network requirements are briefly described below:

- Phase 1: Identification of seasonality at municipality level:
  - Calculation of monthly traffic per municipality

- Adjustment of monthly traffic to account for the structural growth in traffic observed over the years[7]
- Identification of the busiest month of the year
- Identification of seasonal behaviours that are offset by structural growth. For instance, if traffic in later months of the year exceeds the seasonal traffic peak in the year, it can be argued that network dimensioning will be determined by the greater requirements in later months of the year, than by the seasonal peak earlier in the year[8]
- Preliminary assessment of seasonality. Municipalities are preliminary classified as seasonal if the adjusted traffic in the busy month is at least 10%, 30% or 50% (depending on the selected scenario) higher than the yearly average. The results obtained under each threshold scenario can be assessed by selecting the desired option in the control panel of the model (these options are only available for the countries which provided enough information to assess their seasonal patterns).

[7] This adjustment is performed to distinguish between seasonality of traffic and structural annual growth in traffic, which is particularly relevant in the case of mobile data traffic.

[8] This assumption is consistent with the approach adopted by the EC in previous cost studies, where it was assumed that structural growth in mobile broadband over the course of the year was likely to trump any potential impact of traffic seasonality on network dimensioning.

Exhibit 2.5: Selection of the alternative seasonality threshold scenarios in the model [Source: Axon Consulting]

- Phase 2: Assessment of the relevance of seasonality per geoytpe:
  - Estimation of Jan-April 2022 traffic
  - Calculation of yearly traffic per geotype
  - Assessment of geotype's materiality: a geotype was split between seasonal / non-seasonal if the seasonal traffic represented more than 15% of the total traffic in the geotype. One country was identified as seasonal if at least one of its geotypes was considered seasonal
- Phase 3: Identification of traffic in the busy month per service:
  - Identification of the busy month in FY2022 at municipality level
  - Calculation of busy month traffic per geotype
  - Calculation of the percentage of traffic in the busiest month of the year, per geotype

Please refer to section 3.1.10 for more detailed indications about how seasonality and traffic patterns were assessed in the model.

2.5. Domestic data demand forecasts

In today's mobile telecom networks, data demand is one of the main drivers for network deployment. Given this reality and the intrinsic uncertainty of future demand trends, the following three scenarios are available with regards to the domestic data demand forecasts to assess how changes in the expected demand trends could affect the results obtained:

- *Base Case growth*. This scenario is defined based on the projection of the historical growth rates of the demand data traffic reported by the stakeholders.
- *Aggressive growth*. This scenario assumes a higher than originally expected growth of the domestic data service.
- *Conservative growth*. This scenario assumes a lower than originally expected growth of the domestic data service.

The specific approach that adopted to set the forecasts under each of these scenarios is thoroughly described in section 3.1.2.3.

The results obtained under each scenario can be assessed by selecting the desired option in the control panel of the model (please refer to the 'User manual' for further indications on how to run the model):

Exhibit 2.6: Selection of the alternative domestic data demand forecast scenarios in the model [Source: Axon Consulting]

2.6. Allocation of common costs based on traffic or customers

Common costs refer to those costs that are not incremental to any given service, hence, corresponding to costs that, in general, present a more fixed nature in the operators' networks.

The model incorporates two scenarios regarding the allocation of common costs for data services:

- *Common costs allocated based on traffic*. This scenario allocates the common costs of data services between traditional services to end-customers and M2M services by taking into account their split of traffic (volumes of GB).
- *Common costs allocated based on customers*. This scenario allocates the common costs of data services between traditional services to end-customers and M2M services by taking into account their split of customers.

The specific approach adopted to set these scenarios is thoroughly described in section 4.2.1.

The results obtained under each scenario can be assessed by selecting the desired option in the control panel of the model (please refer to the 'User manual' for further indications on how to run the model):

Exhibit 2.7: Selection of the common costs' allocation scenarios in the model [Source: Axon Consulting]

3. Model's inputs

The cost model developed is data-intensive and has been populated with the information requested to NRAs (through the data-gathering process that ran from 2nd of August to the 22nd of September 2023) as well as additional publicly available information. All the inputs considered in the cost model are thoroughly described in this section and are split according to their source, as follows:

- Inputs gathered from stakeholders (Section 3.1)
- Geographical inputs from publicly available sources (Section 3.2)
- Other inputs (Section 3.3)

3.1. Inputs gathered from stakeholders

Typically, the main inputs included in Bottom-Up cost models are related to specific characteristics of the market they represent. As such, a significant portion of the inputs included in the cost model was defined based on information reported by stakeholders (NRAs and operators) through the data gathering process.

A brief description of the key milestones of the data gathering process is presented below:

- A Data Request Form and Manual were shared with NRAs on 2 August 2023.
- NRAs answered the Data Request before 22 September 2023.
- The EC/Axon team assessed the completeness and validity[9] of the information received and issued requests for clarifications and missing information on 2 October 2023.
- NRAs answered to the request for clarifications and missing information on 12 October 2023.

In addition to this, additional data submitted by stakeholders as part of the two consultation rounds has been considered when finalizing the model.

The table below recaps the data available and its level of consistency[10]:

[9] See following subsections regarding the validation process.

[10] Assessed through cross-country comparisons with other NRAs' data and/or publicly available reports.

Section	Input	Availability of information	Consistency of information
3.1.1	Market Share	High	High
3.1.2	Demand	High	High
3.1.3	Network Statistics	Medium	Medium
3.1.4	Coverage	High	High
3.1.5	Spectrum	Medium	Medium
3.1.6	Unitary Costs	Medium	Medium
3.1.7	General and Administration Expenses (G&A)	Low	Medium
3.1.8	Traffic distribution per technology	High	High
3.1.9	Average Revenue per User (ARPU)	Medium	High
3.1.10	Traffic patterns and seasonal behaviours	Low	Medium
3.1.11	Percentage of traffic in the busy hour	High	High
3.1.12	Useful Lives	High	High
3.1.13	WACC	High	High
3.1.14	Wholesale specific costs	Medium	Low

Table 3.1: Availability and consistency of the inputs collected from stakeholders [Source: Axon Consulting]

A thorough assessment of the information received from EU/EEA countries for each of the above inputs is presented in the upcoming subsections 3.1.1 to 3.1.14.

Each of these subsections is structured in the following blocks:

- Sources of information
- Input validation and treatment
- Input definition

Sources of information

The 'sources of information' subsection provides a high-level overview of the information provided to the EC/Axon team. In this section we also indicate the level of confidentiality that NRAs and operators indicated should be associated to each piece of information, based on the three levels of confidentiality defined in the Data Request Manual, namely:

- *Confidentiality Level 0 – Public Level:* This confidentiality level is associated with information which is available in the public domain and could be directly shared with or used in other NRAs' models to fill any potential gaps.
- *Confidentiality Level 1 – National Level:* This confidentiality level is associated with information that cannot be disclosed to NRAs from other countries (unless it is anonymised or averaged with data from other NRAs). This information can, however, be disclosed to national stakeholders in the version of the model shared with the NRA.
- *Confidentiality Level 2 – Operator Level:* This confidentiality level is associated with information that cannot be disclosed to any party involved in the process (unless it is anonymised or averaged with data from other operators/countries). In the non-confidential versions of the models, all the inputs classified under this confidentiality level are anonymised or averaged.

Input validation and treatment

The 'Input validation and treatment' section describes the analysis performed to verify the reasonability and validity of the information received, as well as to ensure its completeness and representativeness. These analyses were performed under three different perspectives:

- *Intra-country validation*: The information provided by NRAs was analysed on a stand-alone basis to verify that it was reasonable and consistent.
- *Inter-country validation*: The information provided by NRAs was also cross-checked against the data reported by other EU/EEA NRAs. The objective of this assessment was to identify potential discrepancies between information provided by different NRAs beyond those that can be explained by country specificities. This type of validation exercise was particularly relevant in the review of forward-looking projections.
- *Validation against Public sources*: Public sources such as spectrummonitoring.com[11], GSMA, etc. were consulted to cross-check the reasonability of the information received. Similarly, some relevant KPIs (e.g. number of subscribers, domestic data usage per subscriber, voice usage per subscriber, coverage levels) were also cross-checked against other international sources of that country's data to identify any potential issues with the data provided by NRAs.

[11] Spectrum monitoring website collects spectrum allocation data: https://spectrummonitoring.com/

NRAs were involved in this validation process. For example, when issues were identified with the information provided by an NRA during the verification process, clarifications were requested from that NRA.

Input definition

Finally, the 'input definition' section outlines the methodology used to define the inputs employed to populate the model. This section describes the entire analysis relied on by the EC/Axon team to reach a conclusion on the input value(s) that should be adopted in the cost model and, in particular, on whether it was more appropriate to either use an input value (i) defined at country-level or (ii) defined commonly across EU/EEA countries. The table below describes the inputs defined at (i) national level and (ii) using EEA averages:

Worksheet	Input level
1A MARKET SHARE	National level
1B INP DEMAND	National level
1C INP NW STATISTICS	National level
1D INP COVERAGE	National level
1E INP SPECTRUM	National level
1F INP UNITARY COSTS	EEA average for all countries, except for spectrum and radio-access elements (when sufficient and valid information was provided at country level).
1G INP COST ADJ FACTORS	National level
1H INP COST OVERHEADS	EEA average for all countries
1I INP TECHNOLOGY DIS	National level
1J INP ARPU	EEA average for all countries
2A INP NW	EEA average for all countries
2B INP GEO	National level
2C INP CELL RADIUS	EEA averages for all countries
2D INP DIST POP GEOT	National level
2E INP BUSY HOUR	National level
2F INP BACKBONE & CORE	National level
2G INP RESOURCES LIFE	EEA average for all countries, except for spectrum concession periods, which are set at national level.
2H INP WACC	National level

Worksheet	Input level
2I INP ERLANG	Country-independent input
2J INP SERVICE SPEC COSTS	EEA-based regressions for all countries. The conversion factor of TAPs to GB for voice is defined at national level.

Table 3.2: Definition of the inputs of the model at national/EEA level [Source: Axon Consulting]

3.1.1. Market Share

Market share information is used to define the size of the reference operator in each EU/EEA country. The market share of the reference operator is defined on a country basis as 1/N, where N is the number of Mobile Network Operators (MNOs) in the national market. In the cases where N is larger than 5, the market share of the reference operator is set to a minimum efficient scale of 20% of the market (in terms of subscribers and traffic).

The market share inputs defined are included in worksheet '1A MARKET SHARE' of the model.

3.1.1.1. Sources of information

Market share information was provided by NRAs through the Data Request Form. They indicated the number of MNOs in the market as well as their market share. The tables below indicate the availability and confidentiality of the data reported by NRAs.

Data availability

Status	Countries
Complete information	AT, BE, BG, CY, CZ, DE, DK, EL, ES, FR, HR, HU, IE, IT, LU, MT, NO, PL, PT, RO, SE, SI, SK
High-priority information provided	-
Not all high-priority information provided	-
No information provided	EE, FI, IS, LI, LT, LV, NL[12]

Table 3.3: Market Share – Data availability [Source: Axon Consulting]

[12] As it will be observed throughout this document, EE, FI, IS, LI, LT, LV and NL did not participate in the data collection process. Therefore, no information about these three countries is presented anywhere in this document.

Data confidentiality

Confidentiality level	Countries
Confidentiality level 0	AT, BE, BG, CY, CZ, DE, DK, ES, HR, HU, IE, IT, LU, SE, SI, SK
Confidentiality level 1	-
Confidentiality level 2	EL, FR, MT, NO, PL, PT, RO

Table 3.4: Market Share – Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.1.2. Input validation and treatment

The information provided by the NRAs was validated by checking that the sum of the market share of all the operators reported (including MNOs and MVNOs) was representative of the total market at country level. Specifically, the sum of market shares was verified to fall within a ±5% range from 100%. No discrepancies were detected.

3.1.1.3. Input definition

The market share of the reference operator is defined at country level. This input is key in determining the amount of traffic that goes through the reference operator's network, its spectrum holdings, etc.

The market share of the reference operator was determined, per country, through the formula presented below:

$$Market\ Share_{refernece\ operator}\ (\%) = max\left(\frac{1}{\#\ MNOs}\ ,20\%\right)$$

Considering the previous formula, the market share considered in countries with 3 MNOs was 33.33%, while it was 25.00% in countries with 4 MNOs. There were no cases in which the number of MNOs reported was lower than 3 or higher than 4.

The following exception was considered based on the feedback received in the consultation processes:

Country	Input adjusted	Issues identified	Approach adopted
BG	▶ Market share	As one MNO only provides wholesale network services to another MNO, both of them have been considered as a unique MNO	33.33% market share was considered (as if there were 3 MNOs).
CY	▶ Market share	Despite only 2 MNOs have reported data, it is known that the Cypriot market has a third MNO	33.33% market share was considered (as if there are 3 MNOs).
SK	▶ Market share	From previous SMART 2017/0091 project, it is known that the fourth MNO in the country heavily relies on National Roaming agreements with other MNOs	33.33% market share was considered (as if there were 3 MNOs).

Table 3.5: Market Share – Adjustments performed [Source: Axon Consulting]

3.1.2. Demand

Traffic demand is defined at country level, per year and per service. It refers to the traffic registered[13] in a country in one full year (sum of all months). In the case of subscribers, these are defined as the annual average number of active users in the country.

The table below lists all the services considered in the model for which demand had to be estimated, as well as the name of the variable associated to each service in the model:

Service	Variable considered in the model
Subscribers	
Subscribers	Subscribers.Domestic.SIM Cards.Retail.Subscribers
Data services	
Domestic Data	Data.Domestic.Domestic Data.Retail.Data Traffic
Roaming Data (EEA)	Data.Roaming (EU/EEA).Roaming inbound.Wholesale.Data Traffic
Roaming Data (Non-EEA)	Data.Roaming (Non-EU/EEA).Roaming inbound.Wholesale.Data Traffic
Voice services	
Domestic Voice – On-net	Voice.Domestic.On Net.Retail.On-net
Domestic Voice - Off-net to national	Voice.Domestic.Outgoing.Retail.Off-net national
Domestic Voice - Off-net to international	Voice.International.Outgoing.Retail.Off-net international
Domestic Voice - Incoming from national	Voice.Domestic.Incoming.Wholesale.Incoming from national
Domestic Voice - Incoming from international	Voice.International.Incoming.Wholesale.Incoming from international
Roaming inbound Voice – Outgoing (EEA)	Voice.Roaming (EU/EEA).Roaming inbound.Wholesale.Outgoing
Roaming inbound Voice – Incoming (EEA)	Voice.Roaming (EU/EEA).Roaming inbound.Wholesale.Incoming
Roaming inbound Voice – Outgoing (Non-EEA)	Voice.Roaming (Non-EU/EEA).Roaming inbound.Wholesale.Outgoing
Roaming inbound Voice – Incoming (Non-EEA)	Voice.Roaming (Non-EU/EEA).Roaming inbound.Wholesale.Incoming
SMS services	
Domestic SMS – On-net	SMS.Domestic.On net.Retail.On-net
Domestic SMS - Off-net to national	SMS.Domestic.Outgoing.Retail.Off-net national
Domestic SMS - Off-net to international	SMS.International.Outgoing.Retail.Off-net international
Domestic SMS - Incoming from national	SMS.Domestic.Incoming.Wholesale.Incoming from national
Domestic SMS - Incoming from international	SMS.International.Incoming.Wholesale.Incoming from international

[13] Including free and invoiced traffic.

Service	Variable considered in the model
Roaming inbound SMS – Outgoing (EEA)	SMS.Roaming (EU/EEA).Roaming inbound.Wholesale.Outgoing
Roaming inbound SMS – Incoming (EEA)	SMS.Roaming (EU/EEA).Roaming inbound.Wholesale.Incoming
Roaming inbound SMS – Outgoing (Non-EEA)	SMS.Roaming (Non-EU/EEA).Roaming inbound.Wholesale.Outgoing
Roaming inbound SMS – Incoming (Non-EEA)	SMS.Roaming (Non-EU/EEA).Roaming inbound.Wholesale.Incoming

Table 3.6: Demand - List of services included in the Model [Source: Axon Consulting]

The demand input involves information corresponding to the past (2022) – referenced as historical demand -, as well as forecasts corresponding to future years (from 2023 to 2032) - referenced as forecast demand -.

The demand information is used to define the traffic requirements that the reference operator must satisfy on a yearly basis and, consequently, it has a large impact on network dimensioning and costing.

The demand inputs are included in worksheet '1B INP DEMAND' of the model.

3.1.2.1. Sources of information

Both historical and forecast demand information were gathered from the NRAs through the Data Request Form. As requested, the NRAs provided the information for each of the services at country level and this was used as the primary source of information to fill in the demand-related inputs of the model.

In order to validate the information received and/or to perform additional analyses, other sources of information were also utilized, namely:

- *Eurostat Population Projections*[14]*:* Official projections on the expected number of inhabitants per country. This information was used to project the number of mobile subscribers into the future through the process described in the input definition section below.

[14] Eurostat's current population projections use 1st January 2022 population as base population and are produced for 28 European countries: all EU-27 Member States and Norway https://ec.europa.eu/eurostat/databrowser/view/tps00002/default/table?lang=en

- *Eurostat Tourism Statistics – Nights spent at touristic accommodation establishments*[15]*:* Number of nights spent at touristic accommodation. This information was used to elaborate the projections of mobile roaming traffic.
- *Annual Reports of NRAs:* Annual reports published by NRAs were a useful source of information to cross-check some relevant KPIs from the data reported.

The tables below indicate the availability and confidentiality of demand data per country.

Data availability

Historic Demand / Demand Forecasts	Available	High-priority information provided	Not all high priority information provided	Not available
Available				
High-priority information provided		MT, PL, RO		
Not all high priority information available		HU	AT, BE, BG, CY, CZ, DE, DK, EL, ES, FR, IT, LU, NO, PT, SK	
Not available			HR, IE, SE, SI	

Table 3.7: Demand - Data availability [Source: Axon Consulting]

[15] Eurostat Tourism Statistics 2022: https://ec.europa.eu/eurostat/databrowser/view/tour_occ_ninat/default/table?lang=en

Data confidentiality

Historic Demand / Demand Forecasts	Confidentiality level 0	Confidentiality level 1	Confidentiality level 2
Confidentiality level 0	AT, CY, DE, ES, IE, LU, NO, SE, SK		DK, HR, SI
Confidentiality level 1			
Confidentiality level 2	PL	RO	BE, BG, CZ, EL, FR, HU, IT, MT, PT

Table 3.8: Demand - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.2.2. Input validation, treatment and definition – Historical demand

Thorough validation and treatment exercises were performed to maximise the consistency, reasonability and completeness of the demand information provided by NRAs. The validation exercises were performed on the two sets of demand information - historical demand and demand forecasts -. Given the relevant differences between the data validation exercises performed for both, these are presented in different subsections below.

Data validation

The historical demand information provided by NRAs was validated by performing the following analyses:

- *Representativeness of the market*: Verification (and adjustment, if required) to ensure that the demand data provided was representative of the whole market.
- *Reasonability of penetration rates*: The number of subscribers in a country was divided by Eurostat population data to verify the reasonability of the resulting penetration rates.

- *Consistency between incoming and outgoing national SMS traffic*: At a national level incoming and outgoing national SMS traffic should be equal. Therefore, in the cases in which this condition did not hold true, the data reported was adjusted to fit this criterion.
- *Reasonability of historical trends*: The goal of this validation was to verify that the historical trends provided were consistent across the years and in some particular cases, consistent across the EU/EEA countries (please refer to the paragraphs below for further indications on the specific consistency checks performed). When a field of information was identified to be inconsistent, even after the clarification process with the NRAs, it was estimated based on EU/EEA averages or other alternative approaches which are described in detail.

Each of these analyses is described in the following subsections.

Representativeness of the market

The information provided for each of the services per country and year was analysed to identify if it was representative of the total market (100% of the market share). This analysis was performed primarily using the comments provided by the NRAs and was complemented by our own assessment of the information to understand if any data could be missing (these cases were clarified with NRAs).

The information reported by NRAs showed that, on many occasions, the data provided did not represent the whole market, but only a percentage of it. Therefore, the values reported had to be adjusted, dividing them by the market share of the operators they represented. The countries for which these adjustments had to be applied are listed below:

Service	Countries in which demand has been adjusted per market share
Subscribers	
Subscribers	CY
Data services	
Domestic Data	CY, LU, PT
Roaming Data (EEA)	DK, IT, LU, PT, RO, SK
Roaming Data (Non-EEA)	DK, EL, IT, LU, PT, RO, SK
Voice services	
Domestic Voice – On-net	CY, DK, LU, PT
Domestic Voice - Off-net to national	CY, DK, FR, LU, PT
Domestic Voice - Off-net to international	CY, DK, LU, PT

Service	Countries in which demand has been adjusted per market share
Domestic Voice - Incoming from national	BE, DK, LU, PT
Domestic Voice - Incoming from international	BE
Roaming inbound Voice – Outgoing (EEA)	BE, DK, FR, IT, LU, PT, RO, SK
Roaming inbound Voice – Incoming (EEA)	BE, DK, EL, FR, IT, LU, PT, RO, SK
Roaming inbound Voice – Outgoing (Non-EEA)	DK, EL, FR, IT, LU, PT, RO, SK
Roaming inbound Voice – Incoming (Non-EEA)	DK, EL, FR, IT, LU, PT, RO, SK
SMS services	
Domestic SMS – On-net	CY, DK, LU, PT
Domestic SMS - Off-net to national	BE, CY, DK, LU, PT
Domestic SMS - Off-net to international	BE, CY, DK, EL, FR, PT, LU
Domestic SMS - Incoming from national	BE, DK, PT, SK
Domestic SMS - Incoming from international	BE, EL, PT, SK
Roaming inbound SMS – Outgoing (EEA)	DK, FR, IT, LU, PT, RO, SK
Roaming inbound SMS – Incoming (EEA)	DK, FR, HU, IT, LU, PT, RO, SK
Roaming inbound SMS – Outgoing (Non-EEA)	BE, DK, EL, FR, IT, LU, PT, RO, SK
Roaming inbound SMS – Incoming (Non-EEA)	BE, DK, FR, HU, IT, LU, PT, RO, SK

Table 3.9: Demand - Data validation – Historical Demand – Demand adjustments per market share [Source: Axon Consulting]

Reasonability of penetration rates

The number of subscribers reported by NRAs was divided by the population per country reported by Eurostat to calculate the yearly penetration rates.

The penetration rates were reviewed to identify significant fluctuations or unexpected results in the EU/EEA (e.g. penetration rates below 90% or above 200%). No issues were identified as a result of this analysis.

Consistency between incoming and outgoing national SMS traffic

At national level, all incoming SMS traffic is expected to be equal to all outgoing SMS traffic. The reason behind is that all SMSs generated towards national numbers should be equal to the total number of SMSs received from national numbers[16]. When this condition was not met, the data provided was adjusted as described below to ensure that both services had exactly the same amount of traffic.

The table below summarises the countries for which this issue was identified and describes the actions taken to ensure consistency.

Country	Input adjusted	Issues identified	Approach adopted
AT, BE, BG, CY, CZ, DE, DK, EL, ES, FR, HR, HU, IE, IT, LU, MT, NO, PL, PT, RO, SE, SI, SK.	▶ Domestic SMS - Off-net to national ▶ Domestic SMS - Incoming from national	The figures provided for off-net to national and incoming from national SMS services did not coincide.	The lowest traffic figure from the two services was adjusted to make it equal to the highest reference.

Table 3.10: Demand - Data validation – Historical demand - Consistency between incoming and outgoing national SMS traffic [Source: Axon Consulting]

Reasonability of historical trends

This analysis was aimed at identifying potential inconsistencies or unreasonable trends in the demand traffic information per service, country and year. The main analyses performed are described below:

- *Reasonability of growth patterns:* The annual growth rates per service from 2019 to 2022 were analysed to identify potential unreasonable growth rates in the information provided by NRAs. The following table summarizes the thresholds used to define which values were considered unreasonable:

[16] Even if SMSs could be sent from or to fixed numbers in some countries, their materiality is expected to be negligible.

Service	Nature of traffic	Minimum threshold	Maximum threshold
Data	Domestic	10%	100%
	EEA Roaming	10%	200%
	Non-EEA Roaming	10%	200%
Voice	Domestic	-25%	30%
	EEA Roaming	-25%	50%
	Non-EEA Roaming	-30%	140%
SMS	Domestic	-30%	50%
	EEA Roaming	-60%	50%
	Non-EEA Roaming	-60%	80%

Table 3.11: Demand - Data validation – Historical demand – Reasonability of trends [Source: Axon Consulting]

Thresholds were defined considering the market dynamics of each service and the reasonable outcomes that should be expected from them.

The following table summarises the adjustments performed on the reported data. In a nutshell, when outliers were identified in a specific country, the values were adjusted as indicated in the following table.

Country	Input adjusted	Issues identified	Approach adopted
DK	▶ Domestic Voice – Incoming from International	Unrealistically low annual growth rate observed from 2019 to 2022 (annual growth lower than -50%), when compared with thresholds observed in other EEA countries.	Based on the 2019 data, the 2022 was estimated by applying an annual growth corresponding to the minimum accepted threshold (-25%), based on information from other EEA countries.
SK	▶ Domestic SMS – On-net	Unrealistically low annual growth rate observed from 2019 to 2022 (annual growth lower than -50%), when compared with thresholds observed in other EEA countries.	Based on the 2019 data, the 2022 was estimated by applying an annual growth corresponding to the minimum accepted threshold (-30%), based on information from other EEA countries..

Table 3.12: Demand - Data validation – Historical demand – Summary of reasonability of trends [Source: Axon Consulting]

- *Cross-country comparison:* The percentage of roaming traffic over the total domestic traffic was compared across EEA references to identify potential outliers. In particular, ratios that deviated by more than ±10% from the EEA average were considered as outliers. No issues were identified.
- *Roaming inbound roamers:* The number of roamer days corresponding to roaming inbound users from EEA and non-EEA countries was checked against Eurostat's data on the number of nights spent at touristic accommodations. In particular, the ratio between roamer days and nights spent at touristic accommodation was calculated. Recognising the high volatility of this ratio, it was decided that any ratio higher than 5 should be considered as an outlier. To this respect, the data reported by Slovakia appeared to be an outlier, as its values were almost three times higher than the next highest value. For this reason, the followed approach was to eliminate the reported values and treat Slovakia in the same way as the other countries that did not report inbound roamers.

The historical traffic demand for all the services per year and per country was therefore validated through the multiple analyses described in this section. Once the historical demand information was validated, this information was treated to further increase its robustness, as explained in the following subsection.

Data treatment

Once the historical demand information was validated, it still required further treatment before it was suitable to be used in the model. This section deals with the modifications performed on the data provided by NRAs and the estimations made in the absence of information. The two modifications performed were as follows:

- *Disaggregation of consolidated data:* Some NRAs provided service level information in an aggregated manner (e.g. only one figure was provided for two different services). This section describes the steps adopted to disaggregate the data into the different services.
- *Estimation of missing information:* This section indicates how the information that was not provided by NRAs was estimated.

A more detailed description of each of these approaches is presented in the next two sections.

Disaggregation of consolidated data

NRAs/operators stated that in some cases they were not able to disaggregate the data provided for the services requested and they provided information in a consolidated manner. In these cases, we had to disaggregate the information provided into the applicable services.

The table below shows the countries for which we had to perform such disaggregation and describes the approach adopted.

Country	Input adjusted	Issues identified	Approach adopted
BE	▶ Roaming inbound Data – EEA and non-EEA	The EEA and non-EEA traffic figures for roaming inbound data services were provided in a consolidated manner.	To disaggregate this information, the average EEA/Non-EEA ratio percentage, based on the information received by other NRAs, has been applied for each of the services.
	▶ Domestic SMS – On-net	The value reported included all SMSs generated in the home network.	The reported value has been adjusted by subtracting the off-net (to national and to international) SMS traffic.
	▶ Roaming inbound SMS – Outgoing and Incoming – EEA	The EEA traffic figures included non-EEA traffic for incoming and outgoing SMS traffic.	The reported values have been adjusted by subtracting non-EEA SMS traffic from EEA traffic figures.
	▶ Roaming inbound users - from EU/EEA countries	The figure of roaming inbound users from EEA countries also included the users from non-EEA countries.	In accordance with the comment provided by the Belgium NRA, these users have been distributed at a ratio of 95%/5% for EEA/non-EEA countries respectively.
FR	▶ Domestic SMS- On-net	The value reported included on-net and off-net to national SMS.	The reported value has been adjusted by subtracting the off-net to national SMS traffic.
IT, SI	▶ Domestic SMS – On-net ▶ Domestic SMS – Off-net international ▶ International SMS – Off-net international	The traffic figures reported for domestic on-net SMS included on-net, off-net national and off-net international SMS traffic.	The reported values have been distributed into the different types of SMS service (on-net, off-net national and off-net international) according to the average distribution of reporting EEA countries.

Country	Input adjusted	Issues identified	Approach adopted
SI	▶ Roaming inbound Voice – Outgoing and Incoming – EEA and non-EEA	The EEA traffic figures included non-EEA traffic for incoming and outgoing voice traffic.	The reported values have been adjusted by subtracting non-EEA voice traffic from EEA traffic figures. The calculation of non-EEA traffic is explained in the following subsection (*Estimation of missing information*).
	▶ Roaming inbound SMS – Outgoing and Incoming – EEA and non-EEA	The traffic figures reported for EEA incoming roaming inbound SMS included all inbound SMS (Outgoing EU/EEA, Non-EU/EEA and Incoming EU/EEA, Non-EU/EEA)	The traffic distribution per services has been estimated through the average ratio of roaming SMS traffic distribution per service from countries that have reported complete information.

Table 3.13: Demand - Data treatment – Historical demand – Disaggregation of consolidated information [Source: Axon Consulting]

Estimation of missing information

It is important to ensure that the demand information corresponding to all services is complete. Missing or inconsistent information for a particular country was estimated based on the information available from that same country and/or making use of EEA averages. The missing data that we had to estimate, and the approach adopted to estimate it are described below:

▶ *Domestic Data*

The following table summarizes the missing information that was estimated as well as the approach adopted to estimate it:

Country	Input adjusted	Issues identified	Approach adopted
IE	▶ Domestic Data	The reported information only covers the first quarter (Q1) of the year.	The value for the entire year was estimated as four times the reported value for Q1.

Table 3.14: Demand - Data treatment – Historical Demand – Estimation of missing information - Domestic data [Source: Axon Consulting]

Roaming Data (EEA and non-EEA traffic)

The following table summarizes the missing information that was estimated as well as the approach adopted to estimate it:

Country	Input adjusted	Issues identified	Approach adopted
IE, NO	▶ Roaming Data (EEA)	No data reported	Estimated as the product of EEA roamer-days of the country and roaming data traffic per EEA roamer-day of countries that share similar statistics in terms of EEA visitor nights per inhabitant.
BE, IE, NO, SI	▶ Roaming Data (Non-EEA)	No data reported	Estimated as the product of non-EEA roamer-days of the country and roaming data traffic per non-EEA roamer-day of countries that share similar statistics in terms of non-EEA visitor nights per inhabitant.

Table 3.15: Demand - Data treatment – Historical Demand – Estimation of missing information - Roaming data [Source: Axon Consulting]

Voice and SMS off-net to national traffic

The following table summarizes the missing information that was estimated as well as the approach adopted to estimate it:

Country	Input adjusted	Issues identified	Approach adopted
NO	▶ Domestic voice – Off-net to national	No data reported	Estimated as the product of domestic on-net voice and the average ratio between domestic off-net to national voice and domestic on-net voice from reporting EEA countries.
FR, IE, IT, NO, SI	▶ Domestic SMS – Off-net to national	No data reported	Estimated as the product of domestic on-net SMS and the average ratio between national off-net SMS and on-net SMS from reporting EEA countries.

Table 3.16: Demand - Data validation – Historical Demand – Estimation of missing information – Voice and SMS off-net to national traffic [Source: Axon Consulting]

- *Voice and SMS On-net traffic*

The following table summarizes the missing information that had to be estimated as well as the approach adopted to estimate it:

Country	Input adjusted	Issues identified	Adopted approach
NO	▶ Domestic Voice – On-net	No data reported	Estimated as the product of incoming from national voice traffic and the ratio between on-net voice traffic and incoming from national voice traffic from reporting EEA countries.
DK	▶ Domestic SMS – On-net	No data reported	Estimated as the product of off-net SMS and the ratio between on-net SMS and off-net SMS from reporting EEA countries.
IE	▶ Domestic SMS – On-net	No data reported	Estimated as the product of on-net voice and the ratio between on-net SMS and on-net voice from reporting EEA countries.
NO	▶ Domestic SMS – On-net	No data reported	Estimated as the product of incoming from national SMS and the ratio between on-net SMS and incoming from national SMS from reporting EEA countries.

Table 3.17: Demand - Data treatment – Historical Demand – Estimation of missing information – Voice and SMS on-net traffic [Source: Axon Consulting]

▶ *Voice and SMS off-net to international traffic*

The following table summarizes the missing information that was estimated as well as the approach adopted to estimate it:

Country	Input adjusted	Issues identified	Adopted approach
IE, NO	▶ International Voice – Off-net International	No data reported	Estimated as the product of off-net national domestic voice and the ratio between off-net international and off-net national voice traffic from reporting EEA countries.
IE, NO, IT, SE, SI	▶ International SMS – Off-net International	No data reported	Estimated as the product of off-net national domestic SMS and the ratio between off-net international and off-net national SMS traffic from reporting EEA countries.

Table 3.18: Demand - Data treatment – Historical Demand – Estimation of missing information - Voice and SMS off-net to international traffic [Source: Axon Consulting]

▶ *Voice and SMS incoming traffic from national*

The following table summarizes the missing information that was estimated as well as the approach adopted to estimate it:

Country	Input adjusted	Issues identified	Adopted approach
IE, IT, SE	▶ Domestic voice – Incoming from national	No data reported	Estimated as the product of domestic on-net voice and the ratio between domestic incoming from national and domestic on-net voice from reporting EEA countries.
LU	▶ Domestic voice – Incoming from national	No data reported for 2022	Estimated as the product of domestic on-net voice and the ratio between domestic incoming from national and domestic on-net voice from reporting EEA countries.
IE, IT, LU, SE, SI	▶ Domestic SMS – Incoming from national	No data reported	Estimated as the product of domestic on-net SMS and the ratio between domestic incoming from national and domestic on-net SMS from reporting EEA countries.

Table 3.19: Demand - Input validation – Historical Demand – Estimation of missing information - Voice and SMS incoming traffic from national [Source: Axon Consulting]

- *Voice and SMS incoming traffic from international*

The following table summarizes the missing information that was estimated as well as the approach adopted to estimate it:

Country	Input adjusted	Issues identified	Adopted approach
IE, IT, NO, SE	▶ International voice – Incoming from international	No data reported	Estimated as the product of incoming from national voice and the ratio between incoming from international and incoming from national voice from reporting EEA countries.
LU	▶ International voice – Incoming from international	No data reported for 2022	Estimated as the product of incoming from national voice and the ratio between incoming from international and incoming from national voice from reporting EEA countries.

Country	Input adjusted	Issues identified	Adopted approach
DK, IE, IT, LU, NO, SE, SI	▶ International SMS – Incoming from international	No data reported	Estimated as the product of incoming from national SMS and the ratio between incoming from international and incoming from national SMS from reporting EEA countries.

Table 3.20: Demand - Input validation – Historical Demand – Estimation of missing information - Voice and SMS incoming traffic from international [Source: Axon Consulting]

▶ *Roaming inbound– Incoming and Outgoing (EEA and non-EEA) for Voice and SMS*

In order to fill in gaps of missing roaming inbound traffic, different approaches were used for each country depending on other information provided by that country, as presented in the table below:

Country	Input adjusted	Issues identified	Approach adopted
ES, IE, NO	▶ Roaming inbound Voice – Incoming (EEA and non-EEA)	No data reported	Estimated as the product of roaming inbound outgoing voice and the ratio between roaming inbound incoming and roaming inbound outgoing voice from reporting EEA countries. This ratio was calculated separately for EEA and non-EEA voice.
SI	▶ Roaming inbound Voice – Outgoing (Non-EEA)	No data reported	Estimated as the product of number of subscribers and the ratio between roaming inbound outgoing and number of subscribers from reporting EEA countries.
	▶ Roaming inbound Voice – Incoming (Non-EEA)	No data reported	Estimated as the product of roaming inbound outgoing voice and the ratio between roaming inbound incoming and roaming inbound outgoing voice from reporting EEA countries.

Country	Input adjusted	Issues identified	Approach adopted
IE, NO	▶ Roaming inbound Voice – Outgoing (EEA and non-EEA)	No data reported	Estimated as the product of roamer-days of the country and roaming inbound outgoing voice per roamer-day of countries that share similar statistics in terms of visitor nights per inhabitant. This calculation was performed separately for EEA and non-EEA voice.
SE	▶ Roaming inbound Voice – Outgoing (EEA and non-EEA)	No data reported	Estimated as the product of roaming inbound incoming voice and the ratio between roaming inbound outgoing and roaming inbound incoming voice from reporting EEA countries. This ratio was calculated separately for EEA and non-EEA voice.
IE, NO	▶ Roaming inbound SMS – Outgoing (EEA and non-EEA)	No data reported	Estimated as the product of roamer-days of the country and roaming inbound outgoing SMS per roamer-day of countries that share similar statistics in terms of visitor nights per inhabitant. This calculation was performed separately for EEA and non-EEA SMS.
SE	▶ Roaming inbound SMS – Outgoing (EEA and non-EEA)	No data reported	Estimated as the product of roaming inbound incoming SMS and the ratio between roaming inbound outgoing and roaming inbound incoming SMS from reporting EEA countries. This ratio was calculated separately for EEA and non-EEA SMS.

Country	Input adjusted	Issues identified	Approach adopted
SI	▶ Roaming inbound SMS – Outgoing (Non-EEA)	No data reported	Estimated as the product of non-EEA roamer-days of the country and roaming inbound outgoing SMS per non-EEA roamer-day of countries that share similar statistics in terms of non-EEA visitor nights per inhabitant.
AT, CZ, DE, EL, ES, IE, IT, NO, SI	▶ Roaming inbound SMS – Incoming (EEA and non-EEA)	No data reported	Estimated as the product of roaming inbound outgoing SMS and the ratio between roaming inbound incoming and roaming inbound outgoing SMS from reporting EEA countries. This ratio was calculated separately for EEA and non-EEA SMS.

Table 3.21: Demand - Input validation – Historical Demand – Estimation of missing information - Roaming inbound traffic for voice and SMS [Source: Axon Consulting]

Input definition

Once validated and treated as described in the paragraphs above, the historical demand data provided by the NRAs was fed into the model.

3.1.2.3. Input validation, treatment and definition – Forecast demand

While in terms of historical demand the main objective was to ensure that the data provided by NRAs was fully representative of the market situation, the validation, treatment and definition of the demand forecasts had also to assess the likelihood of the projections reported by NRAs.

Due to the complexity and service-dependence of these analyses, this section has been split as follows:

- Validation and definition of subscribers’ forecasts
- Validation and definition of domestic data traffic forecasts
- Validation and definition of domestic voice and SMS forecasts
- Validation and definition of roaming data, voice and SMS forecasts

Validation and definition of subscribers' forecasts

This section describes how the subscriber trends provided by NRAs were validated as well as how this input was ultimately defined in the model.

Validation of subscriber trends

The validation of subscriber trends consisted in ensuring the representativeness and consistency with historical trends of the growth rates reported by NRAs. Particularly, when growth rates were indicated to be higher than 15%, these were discarded from our exercise.

However, no values were identified above this threshold and, therefore, no issues were detected, implying that the references provided by the NRAs were considered reasonable and used as such in the construction of the subscribers' forecasts.

Projection of total subscribers

The approach adopted to project the number of subscribers until 2032 depended on the data available. In particular, two different alternatives were designed depending on whether NRAs' forecasts were available and reasonable or not:

- *NRAs' information available (for more than three years) and validated*: The growth rates reported by the NRAs were considered as such to project the number of subscribers. When information was not provided for one or more years, subscriber projections were estimated through a linear regression of the available growth rates.
- *NRAs' information not available (or available for less than three years) or discarded*: The number of subscribers for the 2023-2032 period was calculated based on the historical trend of the growth rates for the period 2019-2022.

Validation and definition of domestic data traffic forecasts

This section describes how the domestic data traffic trends provided by NRAs were validated as well as how this input was ultimately defined in the model.

Validation of data trends

The reasonability of data traffic trends was assessed under the following criteria:

- **Criterion A**: *Accelerating growth trend*. In some cases, we observed that some NRAs reported grow rates that increased over time. Given that growth rates are expected to decelerate in the future, NRAs' forecasts exhibiting increases in growth rates over time were not considered appropriate and were discarded.

- In particular, if the growth rate in year i was higher than the growth rate in year i-1 by more than 2% it was discarded.

- **Criterion B:** *Same trend reported in different years*. We observed that some NRAs reported the same growth rate for the whole period under analysis. These cases are expected to be the result of an over-simplification by NRAs/operators and, therefore, were not considered to be robust enough to be included in the model.
  - If the growth rates reported were equal throughout the period of analysis, then the forecast was discarded.
- **Criterion C**: *Very high values reported*. Some countries reported growth rates that were considered to be unreasonably high, especially when compared to historical trends.
  - When the expected annual growth rates were higher than 50% the forecast was discarded.
- **Criterion D**: *Very low values reported*. Some countries reported growth rates that were considered to be unreasonably low, especially when compared to historical trends.
  - When the expected annual growth rates were lower than 5% the forecast was discarded.
- **Criterion E**: *High growth rates beyond 2026*. While it is still reasonable to expect high growth rates in demand for mobile broadband, we consider it reasonable to expect that demand growth will decline over time.
  - When the expected annual growth rates in mobile data from the year 2027 (included) were higher than 45%, the reference was discarded.

The application of these criteria has resulted in the following outcomes at country level:

Country	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Accepted?
AT	✗	✓	✓	✓	✓	✗
BE	✓	✗	✓	✓	✓	✗
BG	✓	✓	✓	✓	✓	✓
CY	✓	✗	✓	✓	✓	✗
CZ	✗	✗	✗	✓	✗	✗
DE	✓	✓	✓	✓	✓	✓

Country	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Accepted?
DK	✗	✓	✓	✓	✓	✗
EE	NA	NA	NA	NA	NA	NA
EL	✓	✓	✗	✓	✓	✗
ES	✓	✓	✓	✓	✓	✓
FI	NA	NA	NA	NA	NA	NA
FR	✓	✓	✓	✓	✓	✓
HR	✓	✓	✓	✓	✓	✓
HU	✓	✓	✓	✓	✓	✓
IE	✓	✓	✓	✓	✓	✓
IS	NA	NA	NA	NA	NA	NA
IT	✓	✓	✓	✗	✓	✗
LI	NA	NA	NA	NA	NA	NA
LT	NA	NA	NA	NA	NA	NA
LU	✓	✗	✓	✓	✓	✗
LV	NA	NA	NA	NA	NA	NA
MT	✓	✓	✓	✓	✓	✓
NL	NA	NA	NA	NA	NA	NA
NO	✓	✗	✓	✓	✓	✗
PL	✗	✓	✓	✓	✓	✗
PT	✓	✓	✓	✓	✓	✓
RO	✗	✓	✓	✗	✓	✗
SE	✓	✓	✓	✓	✓	✓
SI	✓	✓	✓	✓	✓	✓
SK	✓	✓	✓	✗	✓	✗

Table 3.22: Analysis of criteria used to assess demand mobile trends [Source: Axon Consulting]

Projection of domestic data traffic

In order to project domestic data traffic, we considered it appropriate that these should be somewhat based on historical trends. For this reason, we conducted the validation analysis on NRAs' projections described in the previous section. For those NRAs that met this validation, we used their projections to forecast domestic data traffic in their country. For those that did not meet this validation, as shown in the exhibit below, we applied a common forecasting methodology:

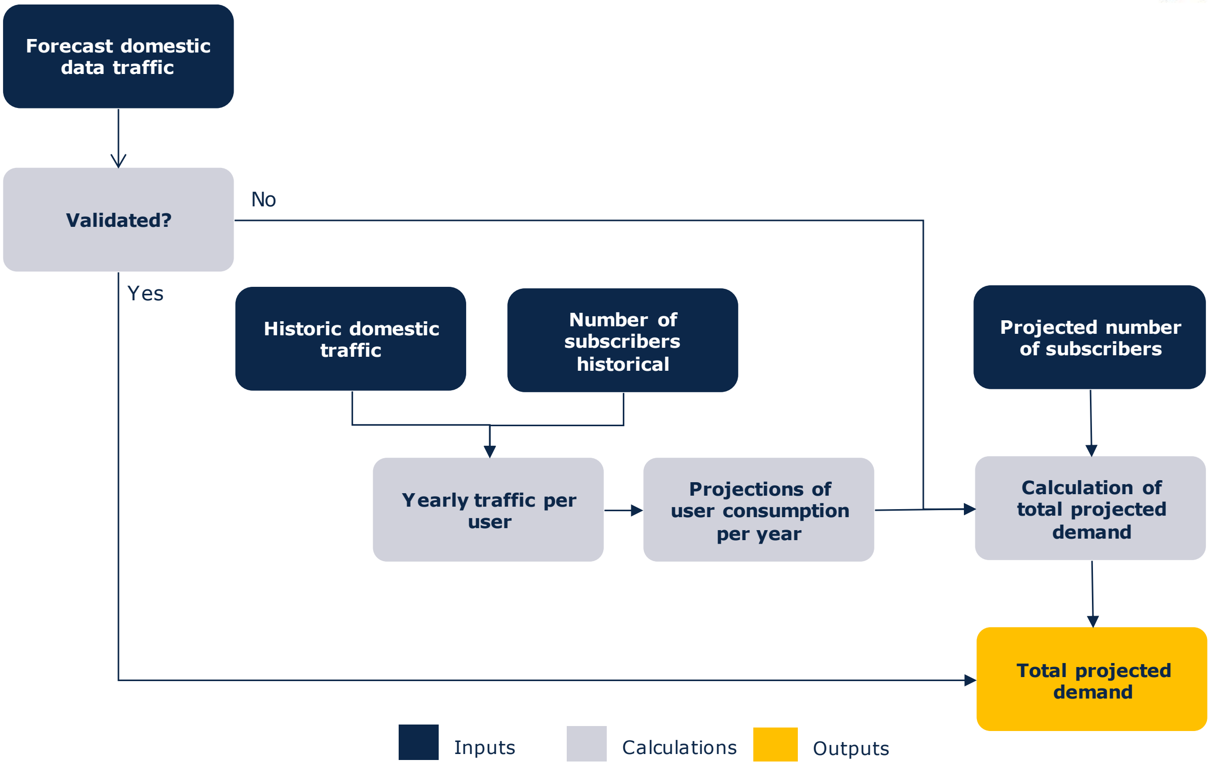

Figure 3.1: Demand – Input definition – Projection of domestic data traffic – YoY growth rate [Source: Axon Consulting]

In the case of NRAs whose demand projections were considered reasonable and thereby valid, these projections had in common a reasonable and relatively homogeneous annual growth rate. The exhibit below shows the average yearly growth rates for domestic data traffic reported by NRAs whose projections we considered valid:

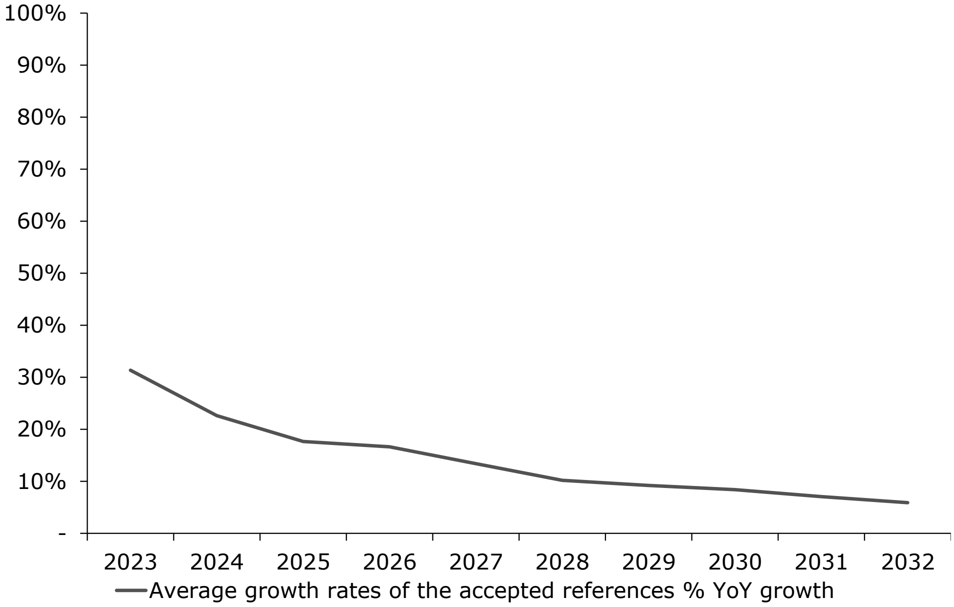

Exhibit 3.1: Demand – Analysis for the input definition – EEA average domestic data traffic YoY growth rate [Source: Axon Consulting from information provided by NRAs]

As the exhibit above shows, growth rates registered in mobile data traffic consumption per user are expected to decrease in the long term[17]. More noteworthy is the fact that the change in the expected growth rate between years is relatively stable over the years. Specifically, as the exhibit below shows, the YoY growth rates in year X are expected to be around 80% of the YoY growth rates registered in year X-1:

[17] This is a conclusion valid in the context of mobile networks that would hypothetically rely on 2G-3G-4G-5G technologies (i.e. the technologies considered in this cost model) over the period considered. In this sense, the above projections are somewhat agnostic regarding the impact that future technologies (6G networks) may have on traffic.

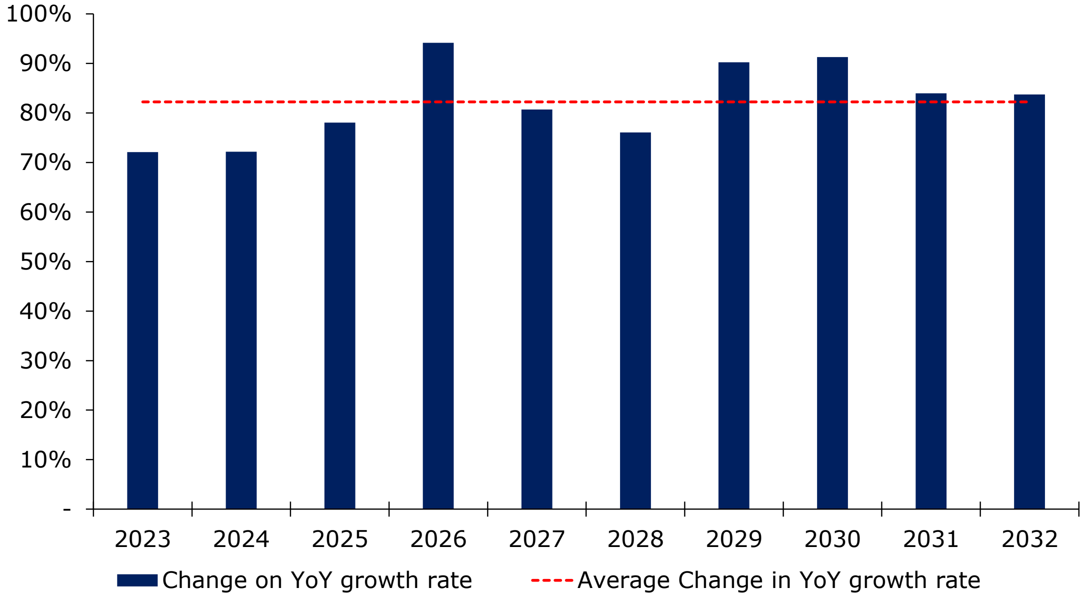

Exhibit 3.2: Demand – Analysis for the input definition – Change in YoY growth rates for the domestic data service [Source: Axon Consulting from information provided by NRAs]

Considering the outcomes of the two charts above, it appeared to be reasonable to project the data traffic consumption per user based on the following approach:

$$DataTraffic\ (year\ i) = DataTraffic\ (year\ i-1) \cdot \left(1 + 82{,}26\% \cdot YoYGrowthRate\ (i-1)\right)$$

It should be noted that this approach was used in two instances: (i) in countries where we did not validate the forecasting provided by NRAs (as explained above) and (ii) in countries where we validated the forecasts provided by NRAs, for missing years in these forecasts.

For illustrative purposes, in the exhibit below we provide a graphical example of a domestic data consumption projection performed from 2023 to 2032, where the yearly traffic growth from 2023 onwards is always 82.26% of the traffic growth rate considered for the previous year. For the avoidance of doubt, this is just an illustrative example:

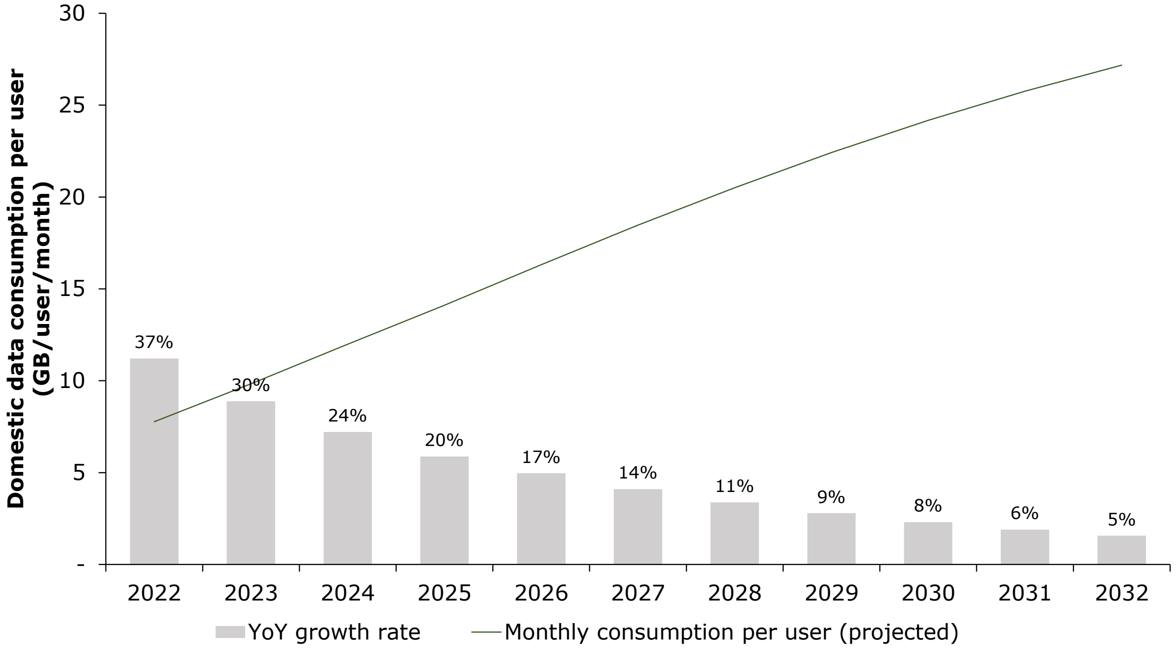

Exhibit 3.3: Demand – Input definition – Illustrative overview of the domestic data traffic projection performed [Source: Axon Consulting]

Additionally, as indicated in section 2.5, two alternative domestic data forecast scenarios were included to assess the sensitivity of the model to the evolution of data traffic (i.e. conservative and aggressive scenarios).

This sensitivity analysis stems from the fact that, while for countries in which their own forecasts were used there is a common agreement on the expected trends, when projections had to be determined by the EC/Axon team, these could be subject to a higher degree of uncertainty.

Particularly, while the same high-level approach was adopted to calculate the demand forecasts under each scenario, we performed the sensitivity analysis by adjusting the growth rate modulation factor (β) presented in the formula below:

$$DataTraffic\ (year\ i) = DataTraffic\ (year\ i-1) \cdot \left(1 + \beta \cdot YoYGrowthRate\ (i-1)\right)$$

In particular, the three scenarios were ultimately defined as follows:

- Base Case scenario (β = 82.26%) as described above.
- Aggressive growth scenario (β = 90%), which implies that a higher domestic data traffic growth is expected into the future.
- Conservative growth scenario (β = 70%), which implies that a lower domestic data traffic growth is expected into the future.

The exhibit below provides a graphical illustration of the results obtained under each of these three scenarios:

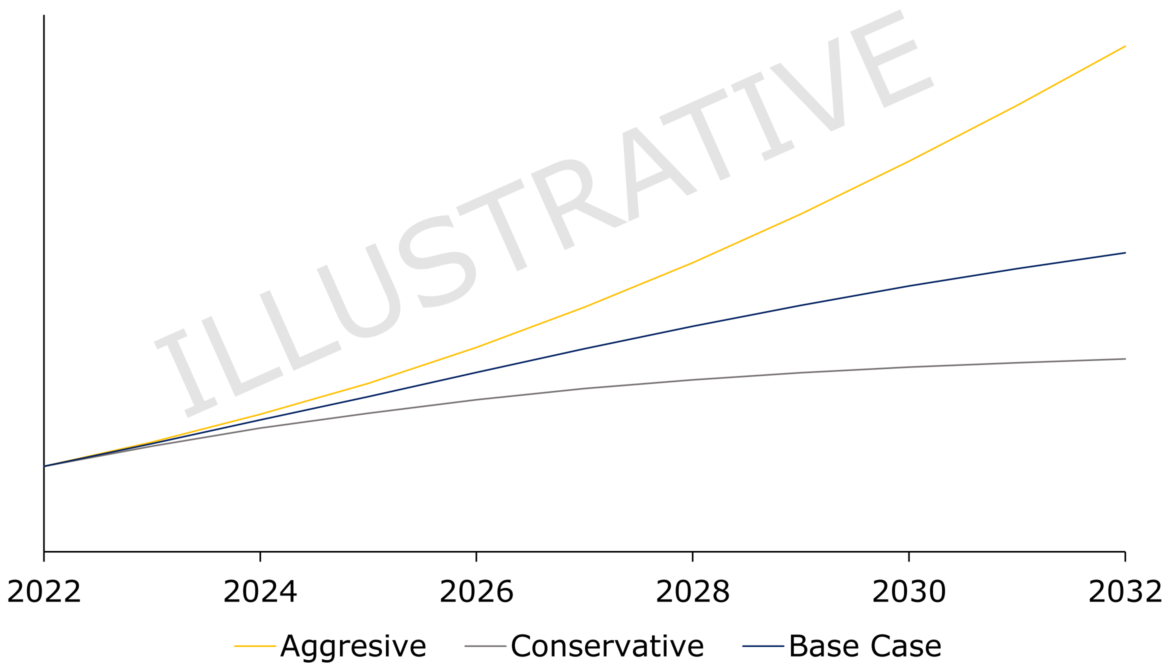

Exhibit 3.4: Demand – Input definition – Data forecast under different scenarios [Source: Axon Consulting based on NRAs' data]

Additionally, in terms of these three alternative scenarios, it should be noted that:

- These scenarios only apply in the countries in which data projections were performed by the EC/Axon team (i.e. when the forecasts provided by the NRAs were used, no differences exist between the three scenarios).
- This sensitivity analysis also affects the calculation of roaming data projections as these are defined as a function of domestic data demand.

Validation and definition of domestic voice and SMS forecasts

This section describes how the domestic voice and SMS trends provided by NRAs were validated as well as how these inputs were ultimately defined in the model.

Validation of voice and SMS trends

In the case of voice and SMS services, we observed that the trends reported by NRAs were significantly different across Member States. In this case, we consider these services to be relatively mature throughout the EEA and, therefore, we expect that their demand is likely to be more stable in future than for mobile broadband services. For this reason, we considered it more appropriate to follow a common forecasting methodology for all countries.

In light of the above, the trends reported by NRAs were discarded in favour of using a common forecasting methodology based on the historical trends registered in each country.

Projection of domestic voice and SMS services traffic

As indicated above, all demand projections were performed at subscriber level. Additionally, as outlined in the section about the validation of demand projections, NRAs' forecasts were not considered for the projection of voice and SMS services' traffic.

In the case of SMS and voice services, as future demand is likely to be relatively more stable than for mobile broadband services, we considered it more appropriate to apply the same forecasting methodology for all countries and to base this methodology on national historical growth rates. In particular, the demand projections for these services were calculated as follows:

$$Traffic\ (year\ i) = Traffic\ (year\ i-1) \cdot \min\left(1 + CAGR\ (2019-2022); 110\%\right)$$

With this formula, the annual growth rates registered in the past (between 2019 and 2022) were projected into the future, allowing a maximum YoY growth rate of 10% to avoid taking into consideration historical growth rates that are not expected to reproduce into the future.

For illustrative purposes, the exhibit below provides a graphical example of the domestic voice consumption projections performed from 2023 to 2032, where the yearly traffic growth from 2023 onwards is always -2.5% in the example presented (equal to the annual traffic growth registered between 2019 and 2022 in this example). For the avoidance of doubt, this is just an illustrative example:

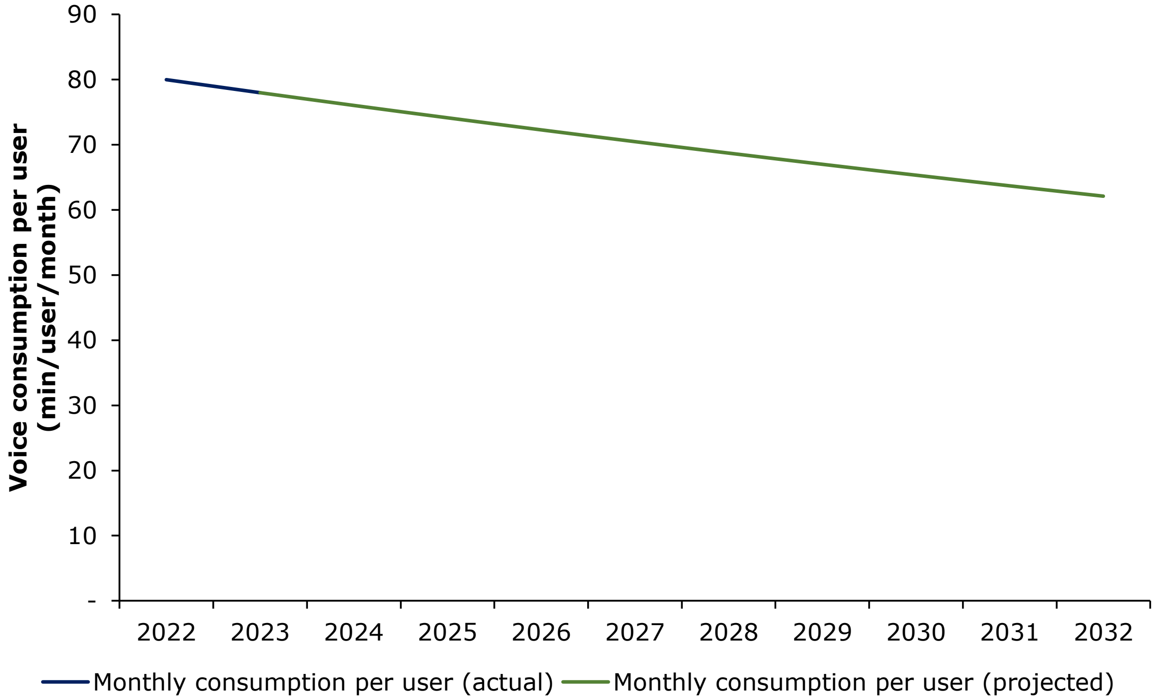

Exhibit 3.5: Demand – Input definition – Illustrative overview of the domestic voice traffic projection performed [Source: Axon Consulting]

Validation and definition of roaming data, voice and SMS forecasts

This section describes how the roaming data, voice and SMS trends provided by NRAs were validated as well as how these inputs were ultimately defined in the model.

Validation of roaming data, voice and SMS trends

Similarly to the situation outlined for domestic voice and SMS services, the trends reported by NRAs for roaming services were significantly different across Member States. At the same time, we recognised the intrinsic complexity the expected trends of roaming services.

At the same time, this implied that the data points available for these projections were also significantly lower than those received for the equivalent domestic services.

Based on the above, we felt it was going to be more consistent to adopt a common forecasting methodology for all countries. In light of this situation, the trends reported by NRAs were discarded in favour of using a common forecasting methodology based on the trends registered in each country.

Projection of roaming data, voice and SMS traffic

The roaming inbound traffic from EEA and non-EEA countries was projected by forecasting separately the number of roamer-days and the average traffic per roamer-day under the steps described below:

- Step 1: Roamer days forecast
- Step 2: Conversion of yearly traffic to consumption per roamer-month
- Step 3: Projection of roaming traffic consumption per roamer day
- Step 4: Calculation of total roaming traffic projections

Step 1: Roamer days forecast

The evolution in the number of roamer days is expected to follow the same pattern as the number of nights spent in touristic accommodation. That is, the trend in the number of roamer days is expected to be fully driven by the trends in tourism.

However, to avoid suffering distortions in the forecasted number of roamer days due to the impact of the Covid-19 pandemic, the annual growth rate of the number of roamer days for the upcoming years has been defined based on the growth rate of nights spent in tourist accommodation for the period 2017-2019, according to Eurostat statistics.

In the EEA countries, the average annual growth rate for the period 2017-2019 was 4.2%. However, when projections are made in our exercise, the applicable growth rate for each individual country is used (instead of the EEA average).

Step 2: Conversion of yearly traffic to consumption per roamer-month

The roaming inbound traffic was converted to consumption of MB, minutes and SMS per roamer and month by dividing the roaming traffic by the number of roamer days and then multiplying it by 30. This was calculated for all historical years only.

Step 3: Projection of roaming traffic consumption per roamer day

The roaming traffic per roamer day was projected in the model, per country, based on the formula below:

$$RoamingTraffic_{roamer\ day}\ (year\ i) = RoamingTraffic_{roamer\ day}\ (i-1) \cdot \left(1 + AverageEEAGrowth(i)\right)$$

Where $AverageEEAGrowth(i)$ refers to the average EEA growth rate of domestic traffic consumption per service and user registered in year i. Using an EEA average growth rate ensures that the growth rate approximates the likely growth rate in volumes from roaming users, which tend to be a mix of EEA nationals.

On the other hand, with regards to the projection of non-EEA roaming traffic, given the complexities involved in the accurate assessment of these trends, and in order to keep consistency with domestic and EEA realities, the same approach as for the projection of EEA roaming traffic was considered.

Step 4: Calculation of total roaming traffic projections

Finally, the projected roaming traffic consumption per roamer day calculated in step 3 above was multiplied by the projected number of roamer days calculated in step 1 to calculate the total roaming traffic generated per country and year.

3.1.3. Network Statistics

Network statistics are needed for the dimensioning algorithms of the model as they provide valuable information on consumers' usage patterns that are relevant to measure network requirements.

The network statistics information comprises voice and data statistics, which are both considered at country level.

The network statistics inputs are included in worksheets '1C INP NW STATISTICS' and '2A INP NW' of the model.

3.1.3.1. Sources of information

Network statistics were provided by NRAs through the Data Request Form in the requested manner and at the country level.

The tables below indicate the availability and confidentiality of the network statistics reported by NRAs per country.

Data availability:

Status	Countries
Complete information	CZ, ES, PL
High-priority information provided	AT, BE, BG, EL, FR, HR, HU, IT, MT, NO, PT, RO, SI, SK
Not all High-priority information provided	CY, DE, DK
No information	IE, LU, SE

Table 3.23: Network Statistics - Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	AT, CY, CZ, DE, ES, SK
Confidentiality level 1	RO
Confidentiality level 2	BE, BG, DK, EL, FR, HR, HU, IT, MT, NO, PL, PT, SI

Table 3.24: Network Statistics - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.3.2. Input validation, treatment and definition – Voice statistics

This section indicates the validation and treatment performed on the voice traffic statistics reported by the NRAs as well as how these inputs were ultimately defined.

Input validation and treatment

The relevant voice statistics requested to NRAs comprised:

- Uncompleted Calls Over Total Calls Percentage – Busy
- Uncompleted Calls Over Total Calls Percentage - Not Taken
- Average Call Duration
- Average Ringing Time

Each of these indicators was validated and defined per country for the following service categories:

- Domestic national
- Domestic international
- Roaming in (EU/EEA)
- Rooming in (Non-EEA)

The main validation exercise performed based on this information consisted in removing inconsistent information. In particular, we ensured that the information considered for each country was reasonable and that figures were not significantly different to general trends observed in other countries (which could be a sign of inaccurate information).

The main conclusions of the exercise are highlighted in the table below:

Country	Voice statistics	Issues identified	Adopted approach
BG	▶ Uncompleted Calls Over Total Calls Percentage – Busy for domestic national	Identified to be significantly lower than the EEA average	Value discarded

Table 3.25: Network Statistics - Input validation– Voice statistics [Source: Axon Consulting]

Input definition

Voice statistics were defined as per the following approach:

- If the statistics reported by an NRA successfully passed our validation exercise, these were directly considered in the model.
- If i) the statistics reported by an NRA were discarded during the validation process or ii) no information was provided by an NRA, EEA average figures were considered.

The following table summarises the voice statistics that had to be estimated based on EEA averages.

Network statistic	Service	Country figures estimated based on EEA averages[18]
Uncompleted calls over total calls percentage - busy	Domestic national	AT, BE, BG, CY, DE, DK, EL, FR, HR, HU, IE, LU, NO, PT, RO, SE, SI, SK
	Domestic international	AT, BE, CY, DE, DK, EL, FR, HR, HU, IE, LU, NO, PT, RO, SE, SK, SI
	Roaming in Voice (EU/EEA)	AT, BE, BG, CY, DE, DK, EL, FR, HR, HU, IE, LU, NO, PT, RO, SE, SI, SK
	Roaming in Voice (Non-EU/EEA)	AT, BE, BG, CY, DE, DK, EL, FR, HR, HU, IE, LU, NO, PT, RO, SE, SI, SK
Uncompleted calls over total calls percentage - not taken	Domestic national	AT, BE, CY, DE, DK, EL, FR, HR, HU, IE, LU, NO, PT, RO, SE, SI, SK
	Domestic international	AT, BE, CY, DE, DK, EL, FR, HR, HU, IE, LU, NO, PT, RO, SE, SI, SK
	Roaming in Voice (EU/EEA)	AT, BE, BG, CY, DE, DK, EL, FR, HR, HU, IE, LU, NO, PT, RO, SE, SI, SK
	Roaming in Voice (Non-EU/EEA)	AT, BE, BG, CY, DE, DK, EL, FR, HR, HU, IE, LU, NO, PT, RO, SE, SI, SK
Average call duration	Domestic national	AT, BE, EL, HR, IE, LU, NO, PT, RO, SE

[18] Includes countries that did not provide information or that the information they provided was classified as an outlier.

Network statistic	Service	Country figures estimated based on EEA averages[18]
	Domestic international	AT, BE, EL, HR, IE, LU, NO, PT, RO, SE, SI
	Roaming in Voice (EU/EEA)	AT, BE, BG, CY, EL, HR, HU, IE, LU, NO, PT, RO, SE, SI
	Roaming in Voice (Non-EU/EEA)	AT, BE, BG, CY, EL, FR, HR, HU, IE, LU, NO, PT, RO, SE, SI
Average ringing time	Domestic national	AT, BE, BG, CY, DK, EL, HR, HU, IE, IT, LU, MT, NO, PT, RO, SE, SK
	Domestic international	AT, BE, BG, CY, DK, EL, FR, HR, HU, IE, IT, LU, MT, NO, PT, RO, SE, SI, SK
	Roaming in Voice (EU/EEA)	AT, BE, BG, CY, DK, EL, FR, HR, HU, IE, IT, LU, MT, NO, PT, RO, SE, SI, SK
	Roaming in Voice (Non-EU/EEA)	AT, BE, BG, CY, DK, EL, FR, HR, HU, IE, IT, LU, MT, NO, PT, RO, SE, SI, SK

Table 3.26: Network Statistics - Input Definition – Voice statistics [Source: Axon Consulting]

3.1.3.3. Input validation, treatment and definition – Data statistics

This section indicates the validation and treatment performed on the data traffic statistics reported by the NRAs as well as how these inputs were ultimately defined.

Input validation and treatment

The relevant data statistics requested to NRAs comprised:

- Download percentage for 2G data traffic
- Download percentage for 3G data traffic
- Download percentage for 4G data traffic
- Download percentage for 5G data traffic

The following reviewing exercises were performed on the data received:

- *Check for completeness of information:* The split between download and upload traffic was reviewed to ensure it adds up to 100%. 5G data traffic reported by DE and 2G data traffic reported by EL was adjusted to sum up to 100%.

- *Check for outliers:* Data provided was compared to the EEA average to identify potential outliers. In particular, the following safety margins were considered to isolate outliers from the other references:
  - 2G GSM threshold: ±20 percentage points from the EEA average
  - 3G UMTS threshold: ±15 percentage points from the EEA average
  - 4G LTE threshold: ±15 percentage points from the EEA average
  - 5G threshold: ±15 percentage points from the EEA average

  The table below shows the outliers identified as part of this reviewing exercise:

Country	Input	Issues identified	Adopted approach
CY, DK	▶ GSM traffic %	Reported download traffic percentage for GSM was significantly above the EEA average.	Values discarded

Table 3.27: Network Statistics - Input validation– Data statistics [Source: Axon Consulting]

Input definition

Data statistics were defined as per the following approach:

- If the statistics reported by an NRA successfully passed our validation exercise (please see Section 3.1.3.2), these were directly considered in the model.
- If i) the statistics reported by an NRA were discarded during the validation process or ii) no information was provided by an NRA, EEA average figures were considered.

The following table summarises the data statistics that had to be estimated based on EEA averages.

Input	Country figures estimated with EEA averages[19]
Download percentage for 2G data traffic	CY, DK, IE, LU, SE
Download percentage for 3G data traffic	CZ, DE, IE, LU, NO, SE
Download percentage for 4G data traffic	IE, LU, SE
Download percentage for 5G data traffic	DK, IE, LU, SE

Table 3.28: Network Statistics - Input Definition – Data statistics [Source: Axon Consulting]

[19] Includes countries that did not provide information or that the information they provided was classified as an outlier.

3.1.4. Coverage

Coverage is defined in the model in terms of population (percentage of population covered) and is introduced at technology (2G, 3G, 4G and 5G) and geotype level. This input is used to calculate the minimum number of passive and active access equipment required to reach the population.

The coverage inputs are included in worksheet '1D INP COVERAGE' of the model.

3.1.4.1. Sources of information

Coverage data was mostly provided by NRAs. The information typically provided was split by technology, and included past, current and forecasted coverage data. In addition to the data provided by NRA, the GSMA's mobile connectivity index[20] was used for validation purposes. The tables below indicate the availability and confidentiality of the coverage data per country reported by NRAs.

Data availability:

Status	Countries
Complete information	CZ, SE
High-priority information provided	AT, BE, BG, CY, DE, EL, FR, HU, IT, LU, MT, PL, PT, RO, SI, SK
Not all High-priority information provided	DK, ES, HR, IE, NO
No information	

Table 3.29: Coverage - Data Availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	AT, BE, CY, DE, HR, IE, IT, LU, NO, PL, PT, SE, SI, SK
Confidentiality level 1	ES
Confidentiality level 2	BG, CZ, DK, EL, FR, HU, MT, RO

Table 3.30: Coverage - Data Confidentiality [Source: Axon Consulting]

[20] GSMA's mobile connectivity index for year 2022: https://www.mobileconnectivityindex.com/index.html#year=2022

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.4.2. Input validation and treatment

The information provided by stakeholders was validated from two different angles:

- *Consistency with GSMA's indicators:* The population coverage per technology provided by each NRA for the year 2022 was compared with the GSMA's mobile connectivity index to validate its consistency.

  This validation was aimed at identifying any clear discrepancies between the data provided by NRAs and the data available at GSMA. Only differences of more than 5 percentage points were investigated.

  The differences observed were clarified with the relevant NRAs and 5G coverage values reported by AT, BE and SE were adjusted in alignment with clarifications received. Additionally, in the case of countries for which the information was incomplete, it was supplemented with data available from GSMA. More specifically, 2G and 3G population coverage in NO and DK was completed with this source.

- *Coverage growth:* Given the constant evolution of mobile telecom networks, population coverage has improved (or at least remained equal) uninterruptedly over the last years. As such, it is expected to keep improving in the future. Evidently, this excludes those cases in which a phase out of a legacy technology (either 2G or 3G) is informed, as in such cases, the model accordingly reflects the phase out by assuming a zero coverage from the end year of the phase out.

  Therefore, and excluding cases of phase out, we checked that the population coverage provided by NRAs per technology showed an upward or flat trend over the years (i.e. it increased or remained equal). As a result of this verification, it was necessary to adjust the population coverage trends per technology in certain cases as shown below:

Country	Technology	Issues identified	Adopted approach
AT	**3G**	The reported value for the period 2022-2024 was lower than that of 2019.	For the period 2022-2024, we established the value of 2019.
BE	**2G**	The reported value for the period 2024-2028 was slightly lower than that of 2023.	For the period 2024-2028, we established the value of 2023.
	4G	The reported value for the period 2024-2032 was slightly lower than that of 2023.	For the period 2024-2032, we established the value of 2023.

Country	Technology	Issues identified	Adopted approach
BG	**4G**	The reported value for 2023 was slightly higher than that of 2024.	For 2023, we established the same value as in 2024.
DK	**5G**	The reported values for the period 2023-2026 were slightly lower than that of 2022.	For the period 2023-2026, we established the value of 2022.
FR	**2G**	The value for the year 2026 was slightly lower than that of 2025.	For the year 2026, we established the value of 2025.
PL	**3G**	The reported value for 2024 was lower than those of 2023 and 2025.	For 2024, we established the average of values related to 2023 and 2025.
PT	**3G**	The reported value for 2023 was lower than those of 2022 and 2024.	For 2023, we established the average of values related to 2022 and 2024.
	4G	The reported values for the period 2024-2026 were slightly lower than that of 2023.	For the period 2024-2026, we established the value of 2023.
RO	**4G**	The reported value for 2023 was lower than those of 2022 and 2024.	For 2023, we established the average of values related to 2022 and 2024.
SK	**2G**	The reported values for the period 2023-2025 were slightly lower than that of 2022.	For the period 2023-2025, we established the value of 2022.
	4G	The reported values for the period 2023-2024 were slightly lower than that of 2022.	For the period 2023-2024, we established the value of 2022.

Table 3.31: Coverage – Countries adjusted trends per technology [Source: Axon Consulting]

3.1.4.3. Input definition

As it may be inferred from the outcomes of the previous paragraphs, historical coverage information was provided by NRAs and adjusted whenever required after the input validation process.

Nevertheless, as indicated at the beginning of this section, coverage is defined in the model for all the timeframe considered (i.e. including forecasts) and at geotype level. Consequently, the following activities were required in order to fully define the coverage inputs in the model:

- Produce coverage forecasts per technology
- Disaggregation of national coverage information into geotypes

Produce coverage forecasts per technology

The coverage projections reported by the NRAs were accepted as such in the definition of the coverage inputs.

Nevertheless, not all NRAs provided coverage projections and some others did not include forecasts up to 2032. Consequently, we had to complement the information collected from NRAs with our own projections. Population coverage forecasts were produced ensuring consistency with historical growth rates and between access technologies.

Therefore, coverage projections were defined manually for each country, ensuring consistency between historical data and the typical evolution of mobile networks. The final values defined can be viewed by stakeholders in the model itself.

Disaggregation of national coverage information into geotypes

The geotypes aggregate municipalities that share similar characteristics in order to ease the dimensioning process. These are further described in Annex A.

One of the key factors considered in the definition of the geotypes was the density of population. Higher densely populated areas were classified as URBAN, while lower densely populated areas were classified as RURAL.

Following operators' common deployment patterns, we considered that when 100% coverage is not reached, operators would first cover URBAN geotypes, then SUBURBAN and finally RURAL. In particular, the formulation adopted is presented below:

$$\%\,PopCoverage\ Geotype\ (i) = \min\left(100\%; \frac{TotalPopCovered - \sum_{n=0}^{i-1} PopCoveredGeotype\ (n)}{PopulationGeotype(i)}\right)$$

Where:

- $\%\,PopCoverage\ Geotype\ (i)$, represents the percentage of population covered in geotype i.
- $TotalPopCovered$, represents the total population covered in a country.
- $\sum_{n=0}^{i-1} PopCoveredGeotype\ (n)$, represents the total population covered in the preceding (more densely populated) geotypes.

- $PopulationGeotype(i)$, represents the total population in geotype i.

3.1.5. Spectrum

The spectrum available per band, technology and year is an essential input of the model used to calculate the minimum number of sites required in a country. Spectrum influences the coverage and capacity capabilities of access sites, in particular:

- **Coverage**: Different spectrum bands have different cell radius and, thus, shape the minimum number of sites required to reach the population. Lower bands have better propagation characteristics while higher bands are more suitable for greater capacity.
- **Capacity:** As the medium over which the radio signal needs to propagate, spectrum bandwidth highly influences the maximum throughput that may be reached in a radio site.

In addition, spectrum licenses constitute a relevant portion of MNOs' costs. These are further discussed in subsection 3.1.6.

The spectrum inputs are included in worksheet '1E INP SPECTRUM' of the model.

3.1.5.1. Sources of information

Spectrum data was mostly provided by NRAs. The data provided was commonly split by technology, and included past, current and forecast information. In addition, other sources of information were also considered so as to validate and complement (wherever necessary) the data provided by NRAs, namely:

- Spectrum monitoring[21]*:* The spectrum allocation information available on this website was used as a sanity check to verify the values provided by NRAs.
- EFIS Database[22]: The information extracted from this database, and more particularly from the ECO Report 03, provides detailed information regarding the spectrum licenses available throughout Europe.

The tables below indicate the availability and confidentiality of the spectrum data reported by NRAs per country.

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[21] Spectrum monitoring website collects detailed spectrum allocation data of mobile operators- https://spectrummonitoring.com/

[22] EFIS Database, ECO Report 03 Information. Link: https://www.efis.dk/views2/report03.jsp

Data availability:

Status	Countries
Complete information	BE, CY, CZ, IE
High-priority information provided	BG, DE, EL, ES, HR, HU, IT, LU, MT, PL, SE, SK
Not all High-priority information provided	FR, NO, PT, RO
No information	AT, DK, SI

Table 3.32: Spectrum - Data Availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	BE, CY, CZ, DE, ES, FR, HR, IE, IT, LU, NO, PL, PT, SE, SK
Confidentiality level 1	RO
Confidentiality level 2	BG, EL, HU, MT

Table 3.33: Spectrum - Data Confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.5.2. Input validation and treatment

The spectrum information was collected from the NRAs for the following bands:

- 700 MHz - FDD
- 800 MHz- FDD
- 900 MHz – FDD
- 1400 MHz - SDL
- 1800 MHz – FDD
- 2100 MHz – FDD
- 2600 MHz – FDD
- 2600 MHz – TDD
- 3400-3800 MHz - TDD
- 26 GHz - TDD

3.1.5.3. Input definition

Given the similarities of spectrum holdings across EEA countries, two main spectrum scenarios were defined:

- Spectrum holdings for countries with 3 MNOs
- Spectrum holdings for countries with 4 MNOs

These scenarios were used to build up the main characteristics of the spectrum holdings in each country and were later fine-tuned to properly represent any relevant differences across countries. Finally, the spectrum holdings at country level were disaggregated per technology.

The steps performed to properly define the spectrum inputs required in the model are described below:

- Step 1: Determination of total spectrum per country
- Step 2: Determine spectrum usage by technology

Step 1: Determination of total spectrum per country

The first step consisted in the identification of the total spectrum available per country, band and year. This activity comprised the following substeps:

- Substep 1.1: Spectrum holdings for countries with 3 and 4 MNOs
- Substep 1.2: Adjustment for availability
- Substep 1.3 Consideration of country-specific differentials

Substep 1.1: Spectrum holdings for countries with 3 and 4 MNOs

Based on the data provided by the NRAs (for historical and projected years), the average spectrum holdings of the reference operator were calculated separately for countries with 3 and 4 MNOs. The table below shows the results obtained for the year 2022:

Band	Spectrum (uplink + downlink) for 2022	
	Reference operator with a Market share of 33% (countries with 3 MNOs)	Reference operator with a Market share of 25% (countries with 4 MNOs)
700 MHz - FDD	20 MHz	10 MHz
800 MHz – FDD	20 MHz	10 MHz
900 MHz – FDD	20 MHz	17.4 MHz
1800 MHz – FDD	50 MHz[23]	30 MHz
2100 MHz – FDD	40 MHz	30 MHz
2600 MHz – FDD	40-50 MHz*	30 MHz
2600 MHz – TDD	20 MHz[24]	10 MHz
3400-3800 MHz - TDD	50-80-90-100-110-120-130 MHz*	
26 GHz - TDD	200-300-400-500-600-700-800 MHz*	

Table 3.34: Spectrum – Input definition - Reference spectrum[25] per band for 2022 [Source: Axon Consulting]. Note (*): See substep 1.3 below.

The averages presented above were already rounded based on the modularity requirements of the underlying access technologies (i.e. 2G requires carriers of 0.2 MHz per link, while 3G, 4G and 5G carriers are of at least 5 MHz per link). Such modularity assessments are also performed in the model itself to validate the appropriateness of the spectrum inputs defined.

At the same time, as the table above shows, the spectrum band of 1400 MHz – SDL was disregarded and not considered in the model, given that a limited number of countries provided information on such band and that this option is not massively adopted in the EEA countries.

Substep 1.2: Adjustment for availability of spectrum bands

Spectrum is a dynamic resource that changes over time, with spectrum awards taking place at different times in each country. While we considered that, in general, most of the

[23] Exceptionally, 30 MHz and 40 MHz have been assumed for MT and PT, respectively, as requested by these countries, given their particular conditions.

[24] Exceptionally, 10 MHz has been assumed for MT, as requested by this country, given its particular conditions.

[25] Includes uplink+downlink

spectrum bands presented in Table 3.34 were available from 2022, there are some countries in which this situation does not hold true.

In particular, the table below shows the countries in which the 700 MHz - FDD, the 2600 MHz - FDD and TDD, 3400-3800 MHz - TDD and 26 GHz – TDD bands, were awarded beyond 2022 or are still to be awarded:

Availability year	700 MHz - FDD	2600 MHz – FDD	2600 MHz – TDD	3400-3800 MHz - TDD	26 GHz - TDD
2023	BG, RO	IE	IE		ES
2024				PL	NO
2025	MT				
2026					MT
2027					BE
2028					
No plans/indications provided about the expected availability year of the band	PL		BE, BG, FR, HR, LU		CY, CZ, DE, FR, HU, IE, LU, PL, PT, RO, SE, SK

Table 3.35: Spectrum – Input definition - Availability year for certain spectrum bands [Source: Axon Consulting]

As presented in this table, these bands were not considered to be available in these countries until the year indicated above. Additionally, we observed that a considerable number of countries did not inform at this stage about any plan regarding the future availability of certain bands. The following considerations were made for the relevant bands:

Band	Considerations followed for countries which have not informed any plan regarding the future availability of these bands
700 MHz - FDD	This case only applies to PL. The model assumes that this spectrum band is not employed by the reference operator in this country.
2600 MHz – TDD	This case applies to BE, BG, FR, HR and LU. The model assumes that this spectrum band is not employed by the reference operator in these countries.

Band	Considerations followed for countries which have not informed any plan regarding the future availability of these bands
26 GHz - TDD	This case applies to CY, CZ, DE, FR, HU, IE, LU, PL, PT, RO, SE and SK. The model assumes that this spectrum band is not employed by the reference operator in these countries.

Table 3.36: Spectrum – Input definition – Considerations followed for certain spectrum bands [Source: Axon Consulting]

Substep 1.3 Consideration of country-specific differentials

Finally, as it was noted in Table 3.34, the average spectrum holdings for a reference operator in the 2600 MHz – FDD, 3400-3800 MHz – TDD and 26 GHz - TDD bands is not homogeneous across countries and it may vary among them.

Accordingly, based on the data reported by countries, their spectrum holdings in these three bands were defined so as to better match their national realities. The spectrum holdings considered in these bands in each of these countries are presented below:

Spectrum band	40 MHz	50 MHz
2600 MHz - FDD	BE, BG, CY, CZ, HR, HU, LU, PT, SK	AT, DE, EL, IE, MT, NO

Table 3.37: Spectrum – Input definition – Spectrum holdings in the 2600 MHz - FDD considered for the countries with 3 MNOs [Source: Axon Consulting]

Spectrum band	50 MHz	80 MHz	90 MHz	100 MHz	110 MHz	120 MHz	130 MHz
3400-3800 MHz - TDD	IT	DE, FR, RO, SE	ES, PT, SK	BE, CY, CZ, DK, HR, IE, MT, PL, SI	LU	AT, BG	EL, HU, NO

Table 3.38: Spectrum – Input definition – Spectrum holdings in the 3400-3800 MHz - TDD band [Source: Axon Consulting]

Spectrum band	200 MHz	300 MHz	400 MHz	500 MHz	600 MHz	700 MHz	800 MHz
26 GHz - TDD	HR, IT	SI	MT	BE, EL, ES	AT, BG	DK	NO

Table 3.39: Spectrum – Input definition – Spectrum holdings in the 26 GHz - TDD band [Source: Axon Consulting]

Step 2: Determine spectrum usage by technology

Once the spectrum holdings of the reference operator are known, it is important to specify how the available spectrum is going to be used by each access technology. The table below shows the approach adopted for each spectrum band, based on the most common trends identified in the usage received from NRAs:

Band	Access technologies in which band is used
700 MHz - FDD	4G and 5G
800 MHz – FDD	4G and 5G
900 MHz – FDD	2G, 3G and 4G
1800 MHz – FDD	2G, 4G and 5G
2100 MHz – FDD	3G, 4G and 5G
2600 MHz – FDD	4G and 5G
2600 MHz – TDD	4G and 5G
3400-3800 MHz - TDD	5G
26 GHz - TDD	5G

Table 3.40: Spectrum – Input definition - Technologies in which each spectrum band can be used [Source: Axon Consulting]

Finally, the assignation of spectrum of those bands shared among various access technologies (700, 800, 900, 1800, 2100 and 2600 MHz bands) was defined manually for each country, by paying attention to the technological needs, in light of the traffic distribution adopted in each country for the different access technologies (see section 3.1.8 for further details on the definition of this input).

3.1.6. Unitary Costs

The unitary costs for the assets are defined in the model for the reference year 2022. This input refers to the CapEx and OpEx costs of the network resources and spectrum licenses, as well as the applicable trends. All cost items are considered in the model in Euros.

Given the relevance of the unitary cost information, a detailed methodology aiming to maximise the quality and robustness of this information was set up, which placed special emphasis on the data reported by the NRAs. The methodology adopted is described in detail throughout this section.

Unitary costs are introduced in the cost model for each of the network resources modelled. These costs are separated between CapEx and OpEx:

- *Unitary CapEx:* Includes the costs associated with the purchase and installation of the network element.
- *Unitary OpEx:* Includes the annual cost of maintenance and operation of the network element. It also includes rental expenses.

In addition to this, separated cost trends for CapEx and OpEx are defined in the cost model in order to assess the evolution of prices over the years.

The unitary cost values used in the cost models are mostly based on EEA averages for the reasons explained further below, with the exceptions of spectrum and radio-access network elements costs, which are set at country level, provided that sufficient and robust information was reported by the stakeholders in each country. Additionally, in order to ensure cross-country comparability between the OpEx cost data reported by NRAs, these values were previously adjusted by PPP (Purchasing power parity) as indicated in section 3.1.6.2.

The unit costs inputs are included in worksheet '1F INP UNITARY COSTS' of the model.

3.1.6.1. Sources of information

The main source of information considered in the definition of the unitary costs of the network resources was the data reported by the NRAs. Even though no NRAs provided information for all the cost items requested, collectively we were able to obtain enough information for each cost item.

Further, in order to process and validate the information reported by the NRAs, the following additional sources of information were considered:

- Euro/European Currency Unit (ECU) exchange rates[26]. The exchange rates reported by Eurostat were used to convert unit prices reported in local currencies to Euros.
- Purchasing power parity index (PPP index): The PPP index was used to homogenise the OpEx prices reported by NRAs with different economic realities. PPP rates for 2022 were obtained primarily from OECD[27] and, if not available from OECD, extracted from World Bank[28].
- Consumer Price Index (CPI) information from IMF[29]: CPI information is used in the model to determine OpEx trends.
- Axon's spectrum award database: Our internal database on spectrum award prices across EEA countries was used in certain cases to complement the spectrum related cost information that was not provided by NRAs. This database has been built up based on the reports issued by NRAs upon the conclusion of a spectrum award process as well as the reports periodically published by the EC.

The tables below indicate the availability and confidentiality of the unitary costs data per country reported by NRAs.

Data availability:

Status	Countries
Complete information	
High-priority information provided	
Not all High-priority information provided	AT, BE, BG, CZ, DE, DK, EL, ES, FR, HR, HU, IE, IT, LU, MT, NO, PL, PT, RO, SI, SK
No information	CY, SE

Table 3.41: Unitary Costs - Data availability [Source: Axon Consulting]

[26] Euro/ECU exchange rates - annual data: https://ec.europa.eu/eurostat/web/products-datasets/-/ert_bil_eur_a

[27] PPP exchange rates from OECD - https://www.oecd-ilibrary.org/economics/data/aggregate-national-accounts/ppps-and-exchange-rates_data-00004-en

[28] PPP exchange rates from World bank - https://data.worldbank.org/indicator/PA.NUS.PPP?end=2022&start=2022&view=bar&year_high_desc=true

[29] International Monetary fund CPI data: http://www.imf.org/external/datamapper/PCPIPCH@WEO/OEMDC/

Data confidentiality:

Confidentiality level	Input
Confidentiality level 0	AT, DE, IE, LU,
Confidentiality level 1	
Confidentiality level 2	BE, BG, CZ, DK, EL, ES, FR, HR, HU, IT, MT, NO, PL, PT, RO, SI, SK

Table 3.42: Unitary Costs - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.6.2. Input validation and treatment

A thorough exercise was performed to ensure the consistency, reasonability and completeness of the data provided by NRAs. This exercise led to the adjustment of a number of figures and to the generation of a robust set of inputs.

Specifically, the activities performed are classified below under the following categories:

- General adjustments
- Data validation

General adjustments

In order to ensure that the references received were comparable to each other, the following adjustments were required:

- *Conversion to EUR:* The information reported in local currency by some NRAs was converted to Euros with the exchange rates reported by Eurostat.
- *PPP adjustments to OpEx:* The OpEx figures reported by NRAs were adjusted with the PPP index to allow for comparison under equivalent economic conditions. The formula used is presented below:

$$OpEx_{ADJ} = OpEx \times (1 - \%labourCosts) + \frac{OpEx}{PPPindex} \times \%laborCosts$$

  Where:

  - $\%labourCosts$ refers to the percentage that labour costs represent over an MNO's network OpEx and it was extracted as an EEA average based on the data reported by NRAs.

- $PPPindex$ is the 2022 PPP of the country referenced to the EU27 average.

Data validation

The adjustments performed in the previous section were aimed at ensuring that the unitary costs were comparable throughout EEA countries. The data validation process was aimed at identifying and removing potential outliers to ensure the representativeness of the figures considered.

The identification of outliers was performed using two different approaches, both based on the number of references received for an input:

- When the number of references collected was less than 4, a manual comparative exercise was performed to review the reasonability of each of the sources. When discrepancies were detected, these were considered as outliers.
- When the number of references collected was 4 or more, the values that fell within the top or bottom 20% of the references collected were discarded as outliers. This threshold was set with the objective to maximise the consistency and reasonability of the references considered; on average, the adoption of this approach reduced the average standard deviation of the references considered by more than half.

While the above considerations were adopted to validate the unitary costs provided for most network elements, some alternative approaches had to be adopted for some resource categories due to their nature:

- *Access Sites.* The information reported by NRAs in the data gathering phase was cross-checked against the EEA average as well as data reported by the stakeholders in their P&L and Fixed Asset Register (FAR). As a result, when the values reported by stakeholders were identified not to be in line with the underlying data in their P&L/FAR or with the EEA averages, these were discarded. The specific adjustments introduced into the data received are described below:

Country	Input adjusted	Issues identified	Approach adopted
CZ	▶ CapEx	Values reported were significantly below the EEA average.	Values provided were discarded. An EEA average was used instead.
HR	▶ CapEx ▶ OpEx	Values reported were significantly above the EEA average.	Values provided were discarded. An EEA average was used instead

Table 3.43: Unitary Costs - Input validation – Access sites costs [Source: Axon Consulting]

- *Single RAN:* In order to validate the Single RAN prices reported by stakeholders, the following criteria were assessed:
  - Comparison with the EEA average. Unit prices that proved to be significantly above (>100%) or below (<50%) of the EEA average were discarded.
  - Cross-check against the data reported by the stakeholders in their P&L and Fixed Asset Register (FAR). When differences higher than 35% were identified, the unit costs reported were discarded.

  Based on this, the following table summarises the adjustments performed.

Country	Input	Issues identified	Adopted Approach
RO	OpEx	Values reported were significantly below the EEA average.	Values provided were discarded. An EEA average was used instead.
SK	OpEx	Values reported were significantly above the EEA average.	Values provided were discarded. An EEA average was used instead

Table 3.44: Unitary Costs - Input validation – Single RAN costs [Source: Axon Consulting]

- *Spectrum costs*. Given the inherent differences in spectrum costs associated to auctions in each country, it was not appropriate to perform the same validation exercise adopted for the other resource categories. Instead, spectrum costs were validated by means of a comparison with Axon's internal spectrum database as well as with spectrum costs from the previous EC's model from SMART 2017/0091.

  The following table summarizes the adjustments introduced to the spectrum data provided by NRAs:

Country	Input	Issues identified	Adopted Approach
HR	CapEx 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2600 MHz and OpEx 3600 MHz	The prices reported were not aligned with public references about spectrum auctions in HR.	The prices for each band were obtained from the following source: https://www.hakom.hr/en/hakom-has-awarded-spectrum-to-mobile-communications-networks/10500
IT	All spectral bands	The reported prices presented unrealistically low values, suggesting a potential error in the reported unit.	Values discarded.

Country	Input	Issues identified	Adopted Approach
LU	▶ All spectral bands	The allocated bandwidth for each spectral band has not been specified.	Values discarded.

Table 3.45: Unitary Costs - Input validation – Spectrum unit prices [Source: Axon Consulting]

3.1.6.3. Input definition

The next step consisted in the estimation of the applicable unitary costs and associated trends for both OpEx and CapEx categories to be entered into the model. The sections below provide further indications on the approach used to define the unit costs and associated trends:

- Unit CapEx and OpEx prices
- CapEx trends
- OpEx trends

Unit CapEx and OpEx prices

This section describes the steps required to define the unitary CapEx and OpEx information used in the model. The default approach was to calculate the average of the data points collected, excluding the outliers as described in the previous section.

In terms of unitary CapEx, this approach was adopted due to the reasons indicated below:

- **Limited availability of information reported by NRAs**. Most countries were not capable of reporting unit cost information for all the network elements. Therefore, if it had been decided to set unit costs at country level, it would have been necessary in any case to include EEA averages. In turn, this approach (combination of country level inputs and EEA averages) would have led to inconsistencies in terms of the comparability between the unit costs considered for different network elements.
- **Relative consistency in the data reported by NRAs**. We observed that in many cases the values reported were reasonably similar across countries (standard deviations of ~50%), implying that there were no huge differences among Member States.
- **Presence of multinational groups**: Many of the largest operators in the EEA are part of larger pan-European telecommunications groups. Typically, in this case the prices obtained by the operators from the same group in different countries would be reasonably similar. In turn, it is also true that, given that in all countries there is at

least one MNO that is part of a multinational group, the reasons that would justify material deviations in the unit costs of the assets are minimised.

- **Consistency with the efficient operator assumption**: The model is not aimed at reflecting the characteristics of any specific operator in any country. Therefore, operator-driven unit cost differentials should be excluded from any cross-country analysis. This is also achieved by considering unified unit costs across Member States.

On the other hand, in terms of OpEx unit costs, even though homogeneously defined for all EEA countries, these are adjusted based on the PPP index for each country. This index compares the PPP levels observed in each EU/EEA country against the EEA average, to which the values introduced in the model are referred to.

This PPP adjustment enables the model to account for differences in labour costs, which constitute a relevant percentage of the network maintenance costs. Particularly, we assumed that the equipment operation and maintenance costs of are a function of:

1. **The cost of the materials**, which are expected to be similar across EU/EEA.
2. **The labour costs**, which are a result of the workforce dedication to maintain/repair the equipment and the hourly costs of staff. While it is assumed that the workforce dedication will be homogeneous across EU/EEA countries, the hourly costs of staff differ across countries and, thus, we considered PPP values reported by Eurostat as a reliable proxy to account for these differences.

Finally, we had to adopt a specific approach in order to estimate the final values in some other specific cases which are described below:

Access sites

The cost of the access sites may vary from country to country given their different macroeconomic conditions. Therefore, the unit cost of these assets was set at country level.

The information about the access sites' costs was provided by NRAs in the data collection process in two different ways: per geotype and as a national weighted average.

Once converted to euros and, in the case of OpEx, adjusted by PPP, the unit costs for the access sites were set directly based on the information reported by NRAs when it had been validated and accepted. Otherwise, when no information was provided by NRAs or when it did not pass this validation process, inputs were set based on an EEA average.

The table below summarises the source of the inputs considered for each country:

Source of information	CapEx	OpEx
Country-specific figures	BE, BG, DK, EL, ES, HU, MT, NO, PL, PT, RO, SK	BG, CZ, DE, EL, ES, HU, MT, NO, PL, PT, RO, SK
EEA average used	AT, CY, CZ, DE, FR, HR, IE, IT, LU, SE, SI	AT, BE, CY, DK, FR, HR, IE, IT, LU, SE, SI

Table 3.46: Unitary Costs – Access sites – Sources of information considered to set the inputs for each country [Source: Axon Consulting]

Single RAN

Similar to the approach adopted for access sites, SingleRAN unit costs were also set at national level to reflect the differences that may exist across Member States.

The methodology adopted to set their unit CapEx and OpEx is described below:

- **CapEx:** Single RAN unit costs were requested per-configuration (e.g. cost of a Single RAN equipment with 2 bands in 2G, 1 band in 3G, 2 bands in 4G and 1 band in 5G) to get a thorough understanding of the nature of these costs. Nevertheless, these are set in the model as a cost per Single RAN cabinet and a cost per 2G/3G/4G/5G band. Accordingly, we had to establish the relationship between both kinds of inputs.

  To achieve this objective, we considered that the cost of each configuration was built up as the cost of a Single RAN cabinet plus the cost of the bands it included, as outlined in the following formula:

$$\begin{aligned} &Cost\ of\ configuration \\ &\quad = Cost\ per\ Cabinet + \#\ 2G\ bands \times Cost\ per\ 2G\ band \\ &\quad + \#\ 3G\ bands \times Cost\ per\ 3G\ band + \#\ 4G\ bands \times Cost\ per\ 4G\ band \\ &\quad + \#\ 5G\ bands \times Cost\ per\ 5G\ band \end{aligned}$$

  Having established this relationship, the following approaches were adopted to extract the information in the manner requested by the model, depending on the number of references provided by NRAs:

  - *When ≥5 configurations were reported*: In this case, we had at least five equations to determine the value of 5 variables, so the system could easily be solved as a mathematical problem.
  - *When <5 configurations were reported*: When we had more variables than equations, an alternative approach was adopted consisting of assessing the ratio between the costs of the country under assessment for the most widely spread configuration (out of those for which information was provided) and the EEA

average cost for that configuration. This ratio was then applied to the EEA averages for the Single RAN cabinet and the 2G/3G/4G/5G bands to get a reasonable proxy of the country-specific costs for each of these elements.

- When the information provided was not accepted or when no information was provided: EEA averages were considered in these cases.

The table below shows a summary of the source of the information considered for each country to set the unit CapEx inputs for the Single RAN equipment:

Source of information	Countries
Country-specific costs	BE, CZ, DE, DK, EL, ES, HR, HU, LU, MT, NO, PL, PT, RO, SI, SK
EEA averages	AT, BG, CY, FR, IE, IT, SE

Table 3.47: Unitary Costs – Single RAN CapEx – Approach followed for each country [Source: Axon Consulting]

- **OpEx**: It was requested and provided as the cost to operate a Single RAN equipment depending on the number of access technologies provided through it (i.e. 1, 2,3 or 4). In order to define this input, we assumed that the cost of operating one band in each technology is the same and that there was a separate cost of operating the Single RAN platform itself. Therefore, the objective when defining this input was to assess a) the cost of operating the Single RAN platform and b) the cost of operating one band.

Based on this, the cost reported by stakeholders could be disaggregated in a fixed and variable component:

$$SRAN\ OpEx\ reported\ for\ i\ technologies$$
$$= Fixed\ OpEx\ of\ the\ SRAN + i \cdot Variable\ OpEx\ per\ band$$

Based on that formulation, our goal consisted in estimating the fixed and variable components that resulted in the minimum square error when compared with the actual data reported by stakeholders. This approach was conducted for all the countries where the data reported was successfully validated.

The following table presents the approach adopted for each EEA country:

Approach adopted	Countries
Country-specific costs	BE, CZ, EL, ES, HR, HU, MT, NO, PT
EEA Average costs	AT, BG, CY, DE, DK, FR, IE, IT, LU, PL, RO, SE, SI, SK

Table 3.48: Unitary Costs – Single RAN OpEx – Approach followed for each country [Source: Axon Consulting]

Transmission links

While the standard process was adopted for most transmission links, other alternatives had to be adopted in the following cases due to the lack of data or the way the information was reported:

- In the case of leased lines, while a few operators did report some CapEx figures (to be understood as one-off payments to get access to the service), most stakeholders reported a value of 0 (or very small values, way below OpEx). Taking this situation into consideration, and while it is true that CapEx one-off fees could apply in some countries, no activation costs were considered in the cost model (only a usage fee – OpEx – was considered for leased lines).
- No information was received for some particular configurations of transmission links regarding OpEx. In those cases, the percentage of OpEx over CapEx observed in other configurations was used to estimate the values that had not been provided.

Core elements

When reporting the unit costs of the core elements, some stakeholders indicated that the cost provided for one platform included the costs of some other elements as well. For instance, in some cases stakeholders indicated that the value provided for the HW component also included the costs from the SW component, or that the cost reported for an SGSN also included the costs of a GGSN.

Consequently, this data had to be rearranged to their corresponding elements by considering the cost references reported by the remaining stakeholders. For instance, if a stakeholder reported the HW and SW costs of a platform together, these were split based on the average split reported by the other stakeholders.

Once the data had been rearranged, all the inputs were defined following the standard process to calculate the EEA average.

Finally, it should be mentioned that, regarding the design of the core network for 5G networks, the model introduces a dimensioning on a per-user basis (i.e., the number of units for the network resource is assumed equivalent to the number of users). The utilization of this approach, instead of a design of the core network based on differentiated core platforms/solutions has been the preferred method due to the lack of detailed data about 5G core platforms and related unit costs received from countries during the data collection phase. This approach is also aligned with common practices most recently observed in the market regarding the commercialization of 5G core equipment by manufacturers, which generally do not differentiate individual costs per platform/function, and instead, they charge operators a global investment for all 5G core related elements. For the determination of the unitary cost per user of the 5G core equipment employed as input within the model, the investments reported by operators for 5G core equipment have been divided by the number of corresponding users. Finally, an EEA average has been obtained.

Spectrum costs

The information reported under this category had to be treated differently as this input was defined at country level. In this case, when NRAs reported the information requested and it was validated, this data was used as such in the model.

In some other cases, while NRAs reported information on spectrum costs, due to the way in which the spectrum auction was designed, the prices paid by MNOs were aggregated between different bands.

Particularly, spectrum costs (which are defined at a country level), were estimated based on different sets of information:

- Data from NRAs: Some NRAs provided detailed information regarding the costs of spectrum and these values were included in the cost model.
- Distribution of bundled costs: In some circumstances, NRAS reported data in an aggregated manner (for instance the cost of a bundle of two spectrum bands), we disaggregated these costs based on typical ratios observed in other EU/EEA countries. In particular, the relevant CapEx per spectrum band was estimated through the following formula:

$$CapEx_i = \text{CapEx} \times \frac{Bandwidth_i \times Scaling\ factor_i}{\sum_{i=0}^{N} Bandwidth_i \times Scaling\ factor_i}$$

  Where,

  - i is the spectrum band whose average price was estimated.
  - CapEx is the total price paid by MNOs to be distributed among the bundled bands.
  - $Bandwidth_i$ is the number of MHz assigned to band i.
  - $Scaling\ factor_i$ represents the relative difference between the costs (per MHz) of the different bands, obtained as an EEA average.
- Previous EC's model from SMART 2017/0091. In cases where a frequency band was not reported but was available from the previous version of the EC's model from SMART

2017/0091 (e.g., if no new auction has taken place since 2018 for a particular country), the spectrum cost used in the previous version was maintained. In the same manner, when the new information reported corresponded to a new auction that was considered not sufficiently representative of the entire spectrum band (i.e., only a reduced number of new MHz have been auctioned), the previous spectrum costs were also maintained. This exclusively occurred in the case of BG for 1800MHz, RO for 800MHz and SK for 900MHz.

- Estimation based on EEA average, for those countries where no other information was available from any of the other sources, an EEA average was used. In these cases, we took an EEA average (in terms of EUR/MHz/inh.) of the prices paid by MNOs in other countries for the same band and multiplied it by the population in the country under analysis.

The following table presents the methodology followed for each of the bands and countries under analysis.

Bands for which costs were estimated	Data from NRAs	Distribution of bundled costs	Previous EC's model from SMART 2017/0091	Estimation based on EEA average
700 MHz	BE, CZ, EL, ES, HR, HU, NO, PT, RO, SI, SK	DK, IE		AT, BG, CY, DE, FR, IT, LU, MT, SE
800 MHz	HR, PT		AT, BE, BG, CY, CZ, DE, DK, EL, ES, FR, HU, IE, IT, MT, NO, PL, RO, SE, SI, SK	LU
900 MHz	BE, FR, HR, HU, PT	DK	AT, BG, CY, CZ, DE, EL, ES, IE, IT, MT, NO, PL, RO, SE, SI, SK	LU
1800 MHz	BE, FR, HR, HU, PT, SK		AT, BG, CY, CZ, DE, DK, EL, ES, IE, IT, MT, NO, PL, RO, SE, SI	LU
2100 MHz	BE, DE, EL, FR, HR, HU, NO, PT, SI	DK, IE	AT, BG, CY, CZ ES, IT, MT, PL, RO, SE, SK	LU
2600 MHz	BG, HR, PT, RO	IE, NO	AT, BE, CY, CZ, DE, DK, EL, ES, FR, HU, IT, MT, PL, SE, SI, SK	LU

Bands for which costs were estimated	Data from NRAs	Distribution of bundled costs	Previous EC's model from SMART 2017/0091	Estimation based on EEA average
2600 TDD MHz	PT, RO	IE, NO		AT, CY, CZ, DE, DK, EL, ES, HU, IT, MT, PL, SE, SI, SK
3400-3800 TDD MHz	BE, BG, CZ, DE, EL, ES, FR, HR, HU, MT, PT, RO, SI, SK	DK, NO		AT, CY, IE, IT, LU, PL, SE
26000 TDD MHz	EL, ES, HR, SI	DK		AT, BE, BG, IT, NO

Table 3.49: Unitary Costs - Input Definition – CapEx Spectrum costs [Source: Axon Consulting].

CapEx trends

CapEx trends were generally based on the average of the information received from stakeholders, after removing outliers (see section 3.1.6.2). The standard deviation was also estimated to verify whether the average obtained showed significant dispersion from the data set.

This approach is consistent with the one defined for the unit CapEx costs, where the same cost is applied throughout the EEA. Moreover, most of the trends reported by NRAs showed similarities across the different countries.

OpEx trends

OpEx is mostly related to labour, maintenance and rental costs. In light of this, cost models typically use some form of general inflation index to forecast OpEx costs. In the model, we used the yearly Consumer Price Index (CPI) information from the International Monetary Fund[30]. This source includes actual and projected information for the 2022-2028 period. For the period between 2029 and 2032, the inflation rate was considered to be equal to 2028.

[30] International Monetary Fund's CPI data: http://www.imf.org/external/datamapper/PCPIPCH@WEO/OEMDC/

3.1.7. General and Administration Expenses (G&A)

G&A expenses are calculated in the model as the product of a G&A ratio and the GBV of the network assets of the modelled operator. The G&A ratio is obtained as the division of the expenses from G&A staff (including finance, regulation and HR departments) and the GBV of an MNO.

The G&A inputs are included in worksheet '1H INP COSTS OVERHEADS' of the model.

3.1.7.1. Sources of information

The main source of information considered in the definition of the G&A was the data reported by the NRAs.

The tables below indicate the availability and confidentiality of the data reported by NRAs.

Data availability:

Status	Countries
Complete information	
High-priority information provided	AT, BE, BG, ES, HU, MT, PL, PT, RO, SI
Not all High-priority information provided	CY, CZ, DE, EL, FR, HR, IT, LU, NO, SK
No information	DK, IE, SE

Table 3.50: G&A - Data Availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	AT, CY, DE, LU
Confidentiality level 1	
Confidentiality level 2	BE, BG, CZ, EL, ES, FR, HR, HU, IT, MT, NO, PL, PT, RO, SI, SK

Table 3.51: G&A - Data Confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.7.2. Input validation and treatment

G&A expenses were calculated based on information provided by each MNO in each country following the steps described below:

- *Step 1:* G&A expenses were calculated as the sum of the costs of staff belonging to the finance, regulation and HR departments.
- *Step 2:* The G&A expenses calculated in the previous step were divided by the Gross Book Value (GBV) of the mobile network assets of the MNO to calculate its G&A ratio.

Once all the G&A ratios were calculated, the figures that were found to lay more than 100% above the average G&A ratio were classified as outliers and were discarded.

3.1.7.3. Input definition

Based on the validated G&A ratios produced after the validation and treatment process, all the G&A ratios calculated where in the range of 0.38% and 1.46%. Due to the homogeneity of the values calculated for the different EEA countries, the G&A ratio was included in the model as a single figure, obtained as the average of the validated references, by value of 0.86%.

3.1.8. Traffic distribution per technology

The traffic distribution per technology refers to the split of traffic (voice, SMS, data) that is handled over each access technology (2G, 3G, 4G, 5G). This input is defined at country level and per year. This input is used in the model to characterise the amount of traffic per service that will go through each access technology and, therefore, it is highly relevant to properly perform the network dimensioning and service costing.

The traffic distribution per technology inputs are included in worksheet '1I INP TECHNOLOGY DIS' of the model.

3.1.8.1. Sources of information

This input was defined based on the information provided by NRAs in the data gathering process.

The tables below indicate the availability and confidentiality of the data reported by the NRAs.

Data availability:

Status	Countries
Complete information	
High-priority information provided	CZ, HU, MT, NO, RO, SK
Not all High-priority information provided	AT, BE, BG, CY, DE, DK, EL, ES, FR, HR, IT, LU, PL, PT, SI
No information	IE, SE

Table 3.52: Traffic distribution per technology - Data Availability [Source: Axon Consulting]

Data confidentiality[31]:

Confidentiality level	Countries
Confidentiality level 0	AT, CY, DE, IT, LU, NO, PL, SI, SK
Confidentiality level 1	ES

[31] The most restrictive confidentiality level is considered (e.g. if part of this information is marked as level '0' and another part as level '1', the country will only appear in the confidentiality level 1 list).

Confidentiality level	Countries
Confidentiality level 2	BE, BG, CZ, DK, EL, FR, HR, HU, MT, PT, RO

Table 3.53: Traffic distribution per technology - Data Confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.8.2. Input validation and treatment

In order to check and validate the consistency of the references collected, the review of the information provided was performed under two different perspectives:

- Verification that the sum of traffic in each technology matched 100%
- Reasonability of YoY trends

Verification that the sum of traffic in each technology matched 100%

Given that traffic must go through either 2G, 3G, 4G or 5G access networks, the sum of the percentages provided by NRAs for each of these technologies had to add up to 100%. The table below summarises the cases in which this condition was not met and the approach adopted to correct them.

Country	Input	Issues identified	Adopted approach
BE	▶ Voice traffic distribution per technology	Percentages for one or more years added up to a figure between 95-105%.	The split was adjusted proportionally to match 100%.
CZ, DE, EL	▶ Data and Voice traffic distribution per technology	Percentages for one or more years in one or more services added up to a figure between 95-105%.	The split was adjusted proportionally to match 100%.
FR, HR, NO, SK	▶ Data traffic distribution per technology	Percentages for one or more years added up to a figure between 95-105%.	The split was adjusted proportionally to match 100%.
MT, RO	▶ SMS traffic distribution per technology	Percentages for one or more years added up to a figure between 95-105%.	The split was adjusted proportionally to match 100%.

Table 3.54: Traffic distribution per technology – Input validation - Technology disaggregation [Source: Axon Consulting]

Reasonability of YoY trends

Mobile market trends suggest that the percentage of traffic to be handled in 2G and 3G networks is expected to decrease, while the opposite holds true for 5G networks. Mixed trends are registered with regards to the traffic in 4G networks depending on multiple country-specific factors.

Consistently, the figures provided were reviewed to verify that the percentage of 2G and 3G traffic showed a declining pattern, while the percentage of 5G traffic showed an uptrend. The cases in which this was not the case are described below, together with the approach adopted:

Country	Input	Issues identified	Adopted Approach
AT	▶ Data GSM 2024 and 2025	The percentage of data traffic over GSM was reported to have an increase in 2024 and 2025.	A linear trend was drawn between the percentage of data traffic over GSM in 2023 and 2026 to soften the trend reported by the NRA. The percentage of traffic in 3G, 4G and 5G was adjusted to ensure that the sum of 2G, 3G, 4G and 5G traffic did still add up to 100%.

Country	Input	Issues identified	Adopted Approach
BE	▶ Data GSM 2027	The percentage of data traffic over GSM was reported to have an increase in 2027.	A linear trend was drawn between the percentage of data traffic over GSM in 2026 and 2028 to soften the trend reported by the NRA. The percentage of traffic in 3G, 4G and 5G was adjusted to ensure that the sum of 2G, 3G, 4G and 5G traffic did still add up to 100%.
	▶ Voice 2024-2026	The reported values for the period 2024-2026, which correspond to only one MNO, are not aligned with the reported values for the period 2022-2023, which correspond to 2 MNOs.	Values for the period 2024-2026 are discarded.
CY	▶ Data LTE 2019-2022	The reported values include LTE and 5G traffic.	Values discarded.
	▶ Voice and SMS 2022	The reported values are not aligned with the EEA average and they clearly correspond to a high-level estimate.	Values discarded.
ES	▶ Data GSM and UMTS 2026	The percentage of data traffic over GSM and UMTS was reported to have an increase in 2026.	A linear trend was drawn between the percentage of data traffic over GSM and UMTS in 2025 and 2027 to soften the trend reported by the NRA. The percentage of traffic in 4G and 5G was adjusted to ensure that the sum of 2G, 3G, 4G and 5G traffic did still add up to 100%.

Country	Input	Issues identified	Adopted Approach
HR	▶ Voice UMTS 2026	The percentage of voice traffic over UMTS was reported to have an increase in 2026.	A linear trend was drawn between the percentage of data traffic over UMTS from 2024 to 2025 to soften the trend reported by the NRA. The percentage of traffic in LTE was adjusted to ensure that the sum of 2G, 3G, 4G and 5G traffic did still add up to 100%.
HR	▶ Data LTE and 5G 2027	The percentage of data traffic over LTE was reported to have an increase in 2027 while it has a decrease over 5G.	A linear trend was drawn between the percentage of data traffic over LTE in 2026 and 2028 to soften the trend reported by the NRA. The percentage of traffic in 5G was adjusted to ensure that the sum of 2G, 3G, 4G and 5G traffic did still add up to 100%.
HR	▶ Voice UMTS 2023	The percentage of voice traffic over UMTS was reported to have an increase in 2023.	A linear trend was drawn between the percentage of voice traffic over UMTS in 2022 and 2024 to soften the trend reported by the NRA. The percentage of traffic in 4G was adjusted to ensure that the sum of 2G, 3G, 4G and 5G traffic did still add up to 100%.
PL	▶ Voice GSM 2025	The percentage of voice traffic over GSM was reported to have an increase 2025.	A linear trend was drawn between the percentage of voice traffic over GSM in 2024 and 2026 to soften the trend reported by the NRA. The percentage of traffic in 3G and 4G was adjusted to ensure that the sum of 2G, 3G, 4G and 5G traffic did still add up to 100%.

Country	Input	Issues identified	Adopted Approach
RO	▶ Voice GSM 2023	The percentage of voice traffic over GSM was reported to have an increase 2023.	A linear trend was drawn between the percentage of voice traffic over GSM in 2022 and 2024 to soften the trend reported by the NRA. The percentage of traffic in 3G and 4G was adjusted to ensure that the sum of 2G, 3G, 4G and 5G traffic did still add up to 100%.
SK	▶ Data UMTS 2023	The percentage of data traffic over UMTS was reported to have an increase in 2023.	A linear trend was drawn between the percentage of data traffic over GSM between 2019-2022 to soften the trend reported by the NRA. The percentage of traffic in 2G, 4G and 5G was adjusted to ensure that the sum of 2G, 3G, 4G and 5G traffic did still add up to 100%.

Table 3.55: Traffic distribution per technology – Input validation – Growth Reasonability [Source: Axon Consulting]

3.1.8.3. Input definition

The traffic distribution input was defined in the model for traffic-related services (e.g. voice, SMS, data) and for subscribers.

The definition of the traffic and subscribers' distribution by technology was based on the information provided by stakeholders that was validated in the previous step.

This section is split below between the definition of historical distribution (including near term projections) and long term projections.

Historical and near-term projections (until 2026)

The definition of the historical and near-term projections for the traffic distribution per technology was performed following the steps described below:

1. The information provided by NRAs, once validated, was considered as the starting point to define this input.

2. In some circumstances when any specific data points were missing between existing data, a linear extrapolation was made.
3. In cases where a country did not provide information, an EEA average was considered.

Long-term projections (from 2027)

The projections performed are based on the validated country-level data in terms of historical and forecast distribution per technology.

The definition of country-specific long-term projections was particularly complex given the limited number of data points reported by some countries. This implied a need for the EC/Axon team to elaborate country-based projections that were both i) coherent in the light of historical trends at country level and ii) consistent with the projections considered for other countries in a similar situation in terms of technological split of traffic.

The complexity of achieving objectives i) and ii) above implied that it was not possible to implement a homogenous and consistent formulation for all countries, as this did always result in a lack of compliance of at least one of these objectives. Instead, a manual, country-by-country approach had to be adopted to ensure the reasonability of the forecasts produced.

In order to implement this approach, the following steps were adopted:

- When forecasts were provided by NRAs and these were accepted, based on their consistency with historical traffic split trends, they were considered as such for the definition of the projections at country level. These countries were classified as "reference countries".
- On the other hand, when no information was reported for a particular country, its forecasts were designed by mimicking the behaviour exhibited by a reference country that had a similar historical trend.

3.1.9. Average Revenue per User (ARPU)

The Average Revenue Per User ('ARPU') is used in the model for the annualization of assets' CapEx under the option of an 'Economic depreciation based on ARPU'. ARPU is introduced in the model for all EEA countries based on an EEA average.

The ARPU inputs are included in worksheet '1J INP ARPU' of the model.

3.1.9.1. Sources of information

The main source of information considered in the definition of the ARPU was the data reported by the NRAs. Further, in order to treat and validate the information reported by the NRAs, the Euro/European Currency Unit (ECU) exchange rates[32] reported by Eurostat were used to convert the ARPU figures reported in local currencies to Euros.

The tables below indicate the availability and confidentiality of the ARPU data per country reported by NRAs.

Data availability:

Status	Countries
Complete information	AT, BE, CZ, NO
High-priority information provided	BG, CY, DK, EL, ES, HU, LU, MT, PL, RO, SK
Not all High-priority information provided	IT, PT
No information	DE, FR, HR, IE, SE, SI

Table 3.56: ARPU - Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	AT, BE, CY, DE, ES, FR, HR, IE, IT, LU, NO, PL, SK
Confidentiality level 1	BG
Confidentiality level 2	CZ, DK, EL, HU, MT, PT, RO, SI

Table 3.57: ARPU - Data Confidentiality [Source: Axon Consulting]

[32] Euro/ECU exchange rates - annual data: http://ec.europa.eu/eurostat/web/products-datasets/-/ert_bil_eur_a

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.9.2. Input validation and treatment

The ARPU figures reported by NRAs was treated and validated following the steps described below:

- *Conversion of ECU to Euros:* Values provided in local currencies were converted to Euros using the Euro/European Currency Unit (ECU) exchange rates.
- *Intra-country validation:* The information provided by NRAs was analysed stand-alone to ensure that the figures reported were consistent with the financial realities of the MNOs. In particular, ARPU information was compared against the division of the revenues reported in the P&L and the subscribers of the MNOs to identify any major discrepancies (understanding that both figures should not be equal but should keep some consistency). No issues were identified.
- *Inter-country validation:* ARPU information was also cross-checked across the EEA countries to identify any potential discrepancies among them that went beyond potential country-specific issues.

  The following table summarises the adjustments performed on the reported data to comply with the *inter-country validation:*

Country	Input adjusted	Issues identified	Approach adopted
CY	▶ ARPU	Values reported are unrealistically low. The reason is that, as informed in the submitted comment, the ARPU only considers revenues of roaming services.	The data reported was discarded.
ES	▶ ARPU	Values reported are unrealistically high when compared to other reporting EEA countries.	The data reported was discarded.

Table 3.58: ARPU – Input validation and treatments – Inter-country validation [Source: Axon Consulting]

3.1.9.3. Input definition

When analysing the information reported by NRAs, it was observed that even though ARPU figures across EEA countries differed, the trends exhibited in all these countries were significantly similar over the years.

Taking into consideration this situation, the ARPU-related inputs were defined in the model following the steps described below:

1. The average YoY ARPU change (in %) was calculated in the EEA countries.
2. A reference ARPU of 10 EUR/month was defined for 2022[33].
3. The ARPU for the years beyond 2022 was calculated as:

$$ARPU(i) = ARPU(i-1)\ x\ ARPU\ Change_{EEA\ Average}\ (i)$$

[33] Please note that the reference ARPU considered has no bearing on the costs produced by the model. Given that ARPU is only employed for the implementation of economic depreciation under a revenues-based production factor, it is only relevant to understand its trend. Therefore, the reference ARPU considered for 2022 could be set to 1, 10 or 100 and the model would deliver the same results as long as the ARPU trend defined in the input is preserved.

3.1.10. Traffic patterns and seasonal behaviours

The mobile traffic distribution over a natural year is typically not flat. Typically, the amount of traffic handled shows an increasing trend, peaking towards the end of the year (due to overall structural traffic growth). In other cases, peaks may be observed during other months of the year (e.g. summer season, winter season, etc.) due to seasonal factors. Understanding and characterising these patterns is key to ensure an accurate modelling of network requirements (which should be able to serve the traffic generated in the peak month) and an appropriate causal cost allocation to services.

This section describes the analyses performed in order to i) calculate the percentage of traffic handled in the busiest month of the year and to ii) identify whether any clear seasonal patterns exist in a country which deserve a disaggregation of geotypes to better reflect these patterns in the cost modelling.

The traffic patterns and seasonality assessment inputs are included in worksheet '2B INP GEO' of the model.

3.1.10.1. Sources of information

Two sources of information were used to assess traffic patterns as well as the existence of seasonality:

- **Traffic per site and month**: This information was reported by the NRAs in the Form by municipality or site, depending on the MNO.
- **Municipalities and their geotype**: This information was extracted from Axon's geographical analysis which is described in detail in section 3.1.14.

The tables below indicate the availability and confidentiality of the data reported by NRAs. Given the dependency between traffic patterns and local realities, this analysis could only be performed for the countries which provided, at least, information with a sufficient level of geographical disaggregation as requested in the Form.

Data availability:

Status	Countries
Complete information	ES, MT, PL
Information provided does not present a sufficient level of geographical disaggregation	HR, IT

Status	Countries
No information	AT, BE, BG, CY, CZ, DE, DK, FR, HR, HU, IE, IT, LU, NO, PT, RO, SE, SI, SK

Table 3.59: Seasonality - Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	
Confidentiality level 1	
Confidentiality level 2	ES, HR, IT, MT, PL

Table 3.60: Seasonality - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.10.2. Input validation and treatment

The information provided by NRAs was validated from different perspectives:

- *Number of sites*: The number of sites reported per MNO was cross-checked, when possible, with the number of sites indicated in the worksheet 'NETWORK ELEMENTS'. No issues were identified.
- *Location of sites*: The coordinates of the sites reported were plotted to verify that they fell within the borders of the country. No issues were identified.
- *Evolution of traffic*: The monthly traffic evolution reported per site was cross-checked, at an aggregated level, with the trends provided in the 'DEMAND&REVENUE TRENDS' to verify their consistency. During this assessment, we observed that information submitted by MT included a presumably illogical decline in data traffic for October, which considerably distorted the results of the analysis. As a result, the information reported was discarded for MT.

3.1.10.3. Input definition

The methodology followed to assess traffic patterns as well as the existence of seasonality is described below through three different phases:

- Phase 1: Identification of seasonality
- Phase 2: Assessment of the relevance of seasonality per geoytpe

- Phase 3: Identification of traffic in the busy month per service
- Phase 4: Cost allocation to services

It should also be mentioned that, in the event that a country has not reported new information to assess the seasonality pattern or information was discarded during the validation process, inputs available on the previous EC's model from SMART 2017/0091 have been maintained.

Phase 1: Identification of seasonality at municipality level

The objective of this first phase was to conclude whether the municipalities of a country were subject to seasonal factors. In order to reach this goal, the following steps were followed:

1. *Calculation of monthly traffic per municipality:* The information reported by NRAs was re-arranged to report it for each of the municipalities available in Axon's geographical analysis. When there was a mismatch between a municipality reported by an NRA and the list of municipalities available in Axon's geographical analysis, the municipality reported by the NRA was assigned to the closest municipality from Axon's geographical analysis.
2. *Adjustment of monthly traffic for structural growth:* Given that the structural growth commonly registered in mobile networks could fade the analysis of seasonality, the monthly traffic per municipality was adjusted for structural growth. This adjustment was performed by means of the CMGR (compound monthly growth rate) registered at a country level between May 2022 and May 2023, following the formula presented below:

$$MonthlyTraffic_{adjusted}(i) = \frac{MonthlyTraffic_{nominal}(i)}{(1 + CMGR)^{n-i}}$$

   Where i refers to the month for which the calculation is being performed and n the total months considered in the analysis (13, from May 2022 to May 2023).
3. *Identification of the busiest month of the year:* This step focused on finding the month with the highest traffic (after the adjustment for structural growth) in each of the municipalities.

4. *Preliminary assessment of seasonality:* If the traffic in the busy month was at least 50%[34] higher than the yearly average, the municipality was preliminarily classified as seasonal.
5. *Seasonality overpassed by structural growth:* Even if a municipality is classified as seasonal after step 4 above, it does not necessarily mean that seasonality is likely to have an impact on network requirements. In particular, it could be the case that the nominal traffic at the end of the year is higher than the nominal traffic registered in the seasonal month. In those cases, the structural growth of traffic would represent the dominant traffic requirements in the year instead of the seasonal month's traffic. In order to assess this situation, a check was conducted to understand if the unadjusted traffic in the seasonal month was above the traffic registered in any other month of the year. If this condition was passed, the municipality kept its seasonal classification. Otherwise, it was considered that seasonality had no effect on network requirements and the municipality was marked as not seasonal.

The following figure provides an illustrative example of a municipality that would be classified as seasonal and a municipality that would be classified as not seasonal under the criteria defined above:

[34] This percentage was defined so as to ensure the representativeness of the analysis. This is, even though a more relaxed rule could have also been defined, it was important to define a rule that was strict enough to ensure that a potential consideration of seasonality would become relevant in the dimensioning of the network.

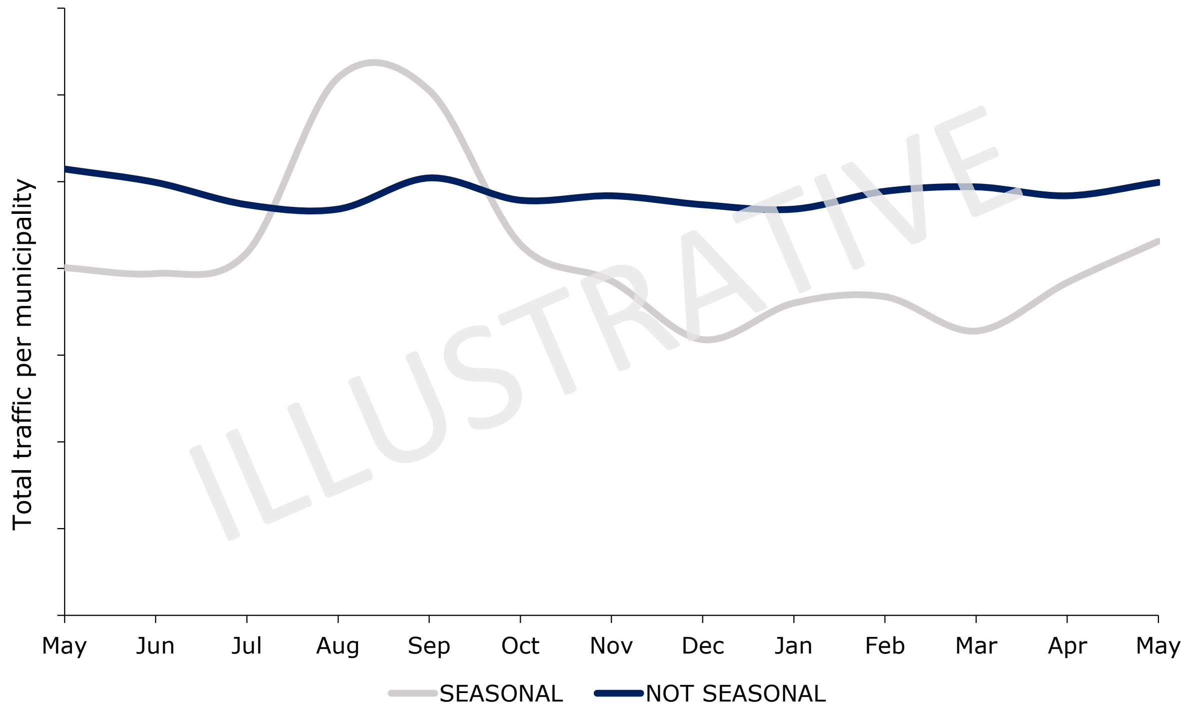


Figure 3.2: Seasonality – Input definition– Illustrative example of seasonality [Source: Axon Consulting]

Phase 2: Assessment of the relevance of seasonality per geoytpe

The goal of this second phase was to identify whether seasonality was relevant enough to merit a disaggregation of geotypes between seasonal and non-seasonal. This is relevant to avoid adding inefficient modelling complexities in the model through the disaggregation of very small geotypes, which add to the complexity of the exercise, with relatively no impact on the end results of the model.

The steps adopted to assess the relevance of seasonality per geotype are described below:

1. *Estimation of Jan-Apr 2022 traffic:* The assessment of seasonality needs to be performed over a full natural year (i.e. from January to December). Consequently, there was a need to estimate the monthly traffic per municipality registered between January and April 2022[35]. This was estimated by extrapolating the May 2022 traffic backwards based on the growth rates registered, at municipality level, between January-April 2023.

[35] Please note that the information was requested for the period May 2022 to May 2023 to reduce the amount requested to the stakeholders.

2. *Calculation of yearly traffic per geotype:* The information captured so far at municipality level was aggregated to a geotype level. This was performed by means of the municipality-geotype relationship available in Axon's geographical analysis as well as the classification of municipalities between seasonal and not seasonal obtained at the end of Phase 1. The result of this step 3 was the yearly traffic per service for each of the following geotypes:

    i. URBAN – SEASONAL
    ii. URBAN – NOT SEASONAL
    iii. SUBURBAN – SEASONAL
    iv. SUBURBAN – NOT SEASONAL
    v. RURAL – SEASONAL
    vi. RURAL – NOT SEASONAL

3. *Assessment of geotype's materiality:* If the total yearly traffic of a sub-geotype (e.g. urban seasonal and urban not seasonal) was higher than 15% of the yearly traffic of the main geotype (e.g. urban), then the disaggregation in subgeotypes was preserved. Otherwise, the main geotype was considered without any disaggregation.

    For instance, if the "RURAL-SEASONAL" geotype collected 10% of the yearly traffic in rural areas, this geotype was not disaggregated and a single "RURAL" geotype was defined. On the contrary, if the seasonal rural geotype collected 20% of the yearly traffic in rural areas, both geotypes (seasonal and not seasonal) were considered.

A country was considered as seasonal when at least one geotype was disaggregated between seasonal and non-seasonal.

The following table below shows the specific geotypes that were disaggregated in each seasonal country:

COUNTRY	URBAN	SUBURBAN	RURAL
SPAIN	▶ URBAN-NOT SEASONAL	▶ SUBURBAN-SEASONAL ▶ SUBURBAN- NOT SEASONAL	▶ RURAL-SEASONAL ▶ RURAL-NOT SEASONAL
CROATIA	▶ URBAN-NOT SEASONAL	▶ SUBURBAN-SEASONAL ▶ SUBURBAN-NOT SEASONAL	▶ RURAL-SEASONAL ▶ RURAL-NOT SEASONAL
GREECE	▶ URBAN-NOT SEASONAL	▶ SUBURBAN-SEASONAL ▶ SUBURBAN-NOT SEASONAL	▶ RURAL-SEASONAL ▶ RURAL-NOT SEASONAL
FRANCE	▶ URBAN-NOT SEASONAL	▶ SUBURBAN-SEASONAL ▶ SUBURBAN-NOT SEASONAL	▶ RURAL-SEASONAL- ▶ RURAL-NOT SEASONAL
MALTA	▶ URBAN- SEASONAL ▶ URBAN-NOT SEASONAL	▶ SUBURBAN-SEASONAL ▶ SUBURBAN-NOT SEASONAL	

Table 3.61: Seasonality – Input definition– Geotypes considered in each country, under the 50% scenario [Source: Axon Consulting]

Phase 3: Identification of traffic in the busy month per service

In this phase, the objective was to calculate the percentage of traffic in the busiest month in each of the geotypes. The steps adopted to achieve this goal are described below:

1. *Identification of the busiest month in FY2022:* This step was carried out to identify the month with the highest nominal traffic for each municipality for the January 2022-December 2022 period.
2. *Calculation of busiest month traffic per geotype:* The information calculated in step 1 above was aggregated at geotype level.
3. *Calculation of the percentage of traffic in the busiest month:* This calculation was performed by dividing the traffic in the busiest month per geotype calculated in step 2 by the yearly traffic per geotype calculated in step 2 from Phase 2. This

calculation was performed per service category (roaming voice, roaming data, domestic voice, domestic data) and per geotype.

When information for a given service category was not available, the same traffic patterns observed for other similar services were considered as a reasonable proxy.

When not all high priority information was provided by NRAs (and therefore, was not possible to carry out an assessment of traffic patterns) a flat traffic pattern was considered.

Phase 4: Cost allocation to services

Finally, based on the busy month traffic obtained from the previous calculation phases, the model obtains i) the number of network elements required to meet the coverage and capacity constraints in each geotype and ii) the annual costs generated by these network elements.

Once the costs per network element and geotype are known, the model performs the cost allocation to services in seasonal and non-seasonal geotypes following an equivalent approach. Specifically, costs are allocated to services based on the product of a routing factors matrix and the busy hour traffic demand per service and geotype.

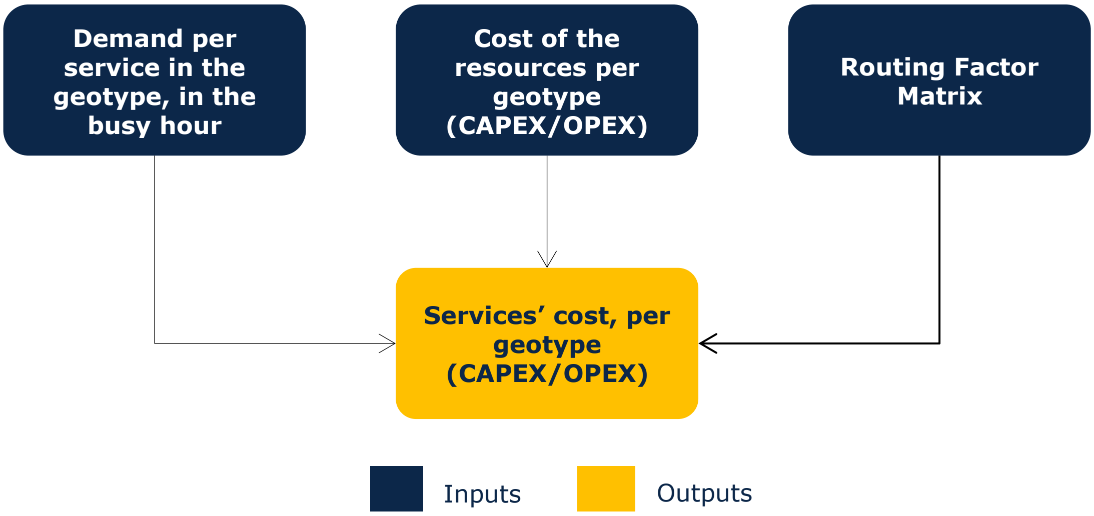


Figure 3.3: Cost allocation process through Routing Factors. [Source: Axon Consulting]

This approach ensures maximum causality with cost generator drivers, while it also recognises the realities observed at geotype level.

For further indications on how costs are allocated to services, please refer to section 5 of the descriptive manual of the model.

3.1.11. Percentage of traffic in the busy hour and in weekdays

The percentage of traffic that is generated in the busy hour of the day is a critical input of a Bottom-Up model, as it characterises the amount of traffic for which the network needs to be dimensioned. The busy hour input in the model is defined per country, service (voice, data) and nature (domestic, EU/EEA roaming, Non-EU/EEA roaming).

The definition of the percentage of traffic in the busy hour is complemented by the characterisation of the percentage of traffic in weekdays. This element provides a more accurate characterisation of the distribution of traffic through the week and ensures that the network is modelled according to the day (weekday or weekend) in which more traffic is generated.

The percentage of traffic in the busy hour and in weekdays inputs are included in worksheet '2E INP BUSY HOUR' of the model.

3.1.11.1. Sources of information

The information provided by NRAs through the Data Request Form was used to calculate the percentage of traffic in the busy hour and in weekdays. The tables below indicate the availability and confidentiality of the information reported by NRAs.

Data availability:

Status	Countries
Complete information	HU, LU, PL
High-priority information provided	AT, ES, MT, NO, RO, SK
Not all High-priority information provided	BE, BG, CY, CZ, DE, DK, EL, FR, HR, IT, PT, SI
No information	IE, SE

Table 3.62: Busy hour and traffic in weekdays - Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality levels	Countries
Confidentiality level 0	AT, CY, DE, LU, PL, SI, SK
Confidentiality level 1	ES
Confidentiality level 2	BE, BG, CZ, DK, EL, FR, HR, HU, IT, MT, NO, PT, RO

Table 3.63: Busy hour and traffic in weekdays – Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.11.2. Input validation and treatment

Both hourly traffic and traffic during weekdays were reviewed to ensure their robustness and maximise the representativeness of the information collected. In particular, the following analyses were performed:

- *Traffic in weekdays – inter-country comparison*: The percentages of traffic provided by NRAs were cross-checked against each other to identify any clear outliers. References were classified as outliers when they deviated by more than 10 percentage points from the EEA average, as these constituted relevant discrepancies with respect to the expected range. The following table summarizes the adjustments performed on the data received.

Country	Input	Issues identified	Adopted approach
AT	▶ Traffic during weekdays for voice and data traffic	The information has not been accurately addressed, as it does not reflect the percentage of total traffic in weekdays for each individual service type. Instead, percentages for the three service types reported add up to 100%.	References discarded
BE	▶ EU/EEA and Non-EU/EEA Roaming traffic during weekdays for voice and data traffic	References were more than 10 percentage points below the EEA average	References discarded

Country	Input	Issues identified	Adopted approach
CY	▶ EU/EEA and Non-EU/EEA Roaming traffic during weekdays for voice and data traffic	EU/EEA Roaming references were more than 10 percentage points above the EEA average. Non-EU/EEA Roaming references were more than 10 percentage points below the EEA average.	References discarded
CZ	▶ EU/EEA and Non-EU/EEA Roaming traffic during weekdays for voice and data traffic	Roaming references were more than 10 percentage points below the EEA average.	References discarded
EL	▶ EU/EEA Roaming traffic during weekdays for voice and data traffic	References were more than 10 percentage points below the EEA average.	References discarded
HU	▶ EU/EEA Roaming traffic during weekdays for voice and data traffic	References were more than 10 percentage points below the EEA average.	References discarded
IT	▶ EU/EEA Roaming traffic during weekdays for data traffic	Reference was more than 10 percentage points below the EEA average.	References discarded
PL	▶ EU/EEA and Non-EU/EEA Roaming traffic during weekdays for voice and data traffic	EU/EEA Roaming references were more than 10 percentage points above the EEA average. Non-EU/EEA Roaming references were more than 10 percentage points below the EEA average.	References discarded

Country	Input	Issues identified	Adopted approach
RO	▶ Non-EU/EEA Roaming traffic during weekdays for data traffic	Reference was more than 10 percentage points below the EEA average.	References discarded
SK	▶ Traffic during weekdays for voice and data traffic	References were more than 10 percentage points below the EEA average.	References discarded

Table 3.64: Busy hour and traffic in weekdays – Input validation – Traffic in weekdays [Source: Axon Consulting]

- *Hourly traffic per service – 100% sum:* The values reported by NRAs were reviewed to ensure that the sum of the hourly traffic distribution added up to 100%. As a result of this review, we observed that this was not the case for the following references, which were discarded:

Country	Input discarded
CZ	▶ Domestic traffic of voice services
IT	▶ Traffic of voice and data services
SK	▶ EU/EEA Roaming traffic of voice services

Table 3.65: Busy hour and traffic in weekdays – Input validation – Hourly traffic per service [Source: Axon Consulting]

- *Hourly traffic per service – Inter-country assessment*: The resulting percentage of traffic in the busy hour in each country was cross-checked against other references to verify that they were not more than 5 percentage points from the EEA average, as these constituted relevant discrepancies with respect to the expected range. As a result of this review, we observed that this was not the case of SK for the traffic distribution of data services. These references were discarded.

3.1.11.3. Input definition

The paragraphs below describe the steps performed to calculate the percentage of traffic generated in weekdays as well as the percentage of traffic generated in the busy hour of a day.

Percentage of traffic generated in weekdays

The percentage of traffic generated in weekdays was set at country level and was calculated as the weighted average, based on demand, of the values reported by the NRAs for the different services (Domestic, Roaming EU and Roaming Non-EU).

When information was missing or discarded, the percentage of traffic generated in weekdays was calculated as an EEA average. The table below indicates the cases in which EEA averages were used:

Service	Countries with estimated information based on an EEA average
Voice traffic	AT, IE, PT, SE, SK
Data traffic	AT, FR, IE, PT, SE, SK

Table 3.66: Busy hour and traffic in weekdays – Input definition – Weekdays traffic percentage [Source: Axon Consulting]

Percentage of traffic generated in the busy hour of a day

When NRAs provided the hourly distribution of traffic for an average day and it successfully passed the validation exercise performed, the busy hour traffic percentage was determined as the highest hourly traffic percentage from the information reported by the NRA.

When information was missing or discarded, the busy hour traffic percentage was calculated by means of an EEA average. The table below indicates the cases in which this approach had to be adopted:

Service	Nature	Countries estimates with EEA average
Subscribers	Domestic	AT, BE, CY, DE, DK, EL, FR, HR, IE, LU, NO, SE, SI, SK
Data traffic	Domestic	CY, DE, DK, IE, IT, SE, SK
	Roaming EEA	CY, DE, DK, FR, IE, IT, SE, SI, SK
	Roaming Non-EEA	CY, DE, DK, EL, FR, HR, IE, IT, MT, NO, PT, SE, SI, SK
Voice traffic	Domestic	CY, CZ, DK, IE, IT, SE
	Roaming EEA	CY, CZ, DK, FR, IE, IT, SE, SI, SK
	Roaming Non-EEA	CY, CZ, DE, DK, EL, FR, HR, IE, IT, NO, PT, SE, SI, SK

Table 3.67: Busy hour and traffic in weekdays – Input definition – Busy hour traffic percentage [Source: Axon Consulting]

3.1.12. Useful Lives

Useful lives represent the expected lifespan of network assets and are used to annualise their capital cost over the period considered in the model.

Assets' useful lives were defined using EEA averages based on the information provided by operators in response to our data request, with the exception of spectrum concession periods, which were set at a country level to keep consistency with license durations applicable in each country. Useful lives are used in the model to implement the economic depreciation profile.

The useful lives inputs are included in worksheet '2G INP RESOURCES LIFE' of the model.

3.1.12.1. Sources of information

NRAs provided all the information required in order to define the assets' useful lives in the model. The tables below indicate the availability and confidentiality of the data reported by NRAs.

Data availability:

Status	Countries
Complete information	BE, BG, DE, DK, ES, HU, HR, NO, PT, RO
Not all information provided	AT, CY, CZ, EL, FR, IT, LU, MT, SI, SK
No information	IE, PL, SE

Table 3.68: Useful lives – Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	AT, CY, DE, HR, LU, MT, NO, SK
Confidentiality level 1	ES, SI
Confidentiality level 2	BE, BG, CZ, DK, EL, FR, HU, IT, PT, RO

Table 3.69: Useful lives – Data Confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.12.2. Input validation and treatment

A thorough validation exercise was performed to ensure the consistency, reasonability and completeness of the data provided by NRAs. This validation was performed from two different perspectives:

- **Intra-country validation**: The information provided by NRAs was analysed on a stand-alone basis to ensure that useful lives corresponding to similar/related resources were consistent. No issues were identified.
- **Inter-country validation**: The values reported by NRAs were cross-checked against each other to identify potential discrepancies among them. In particular, references that were above 100% or below 50% the EEA average were discarded as outliers. The table below shows the outliers identified through this process:

Asset category	Outliers
Site equipment (e.g. cabinet, air conditioner)	SK
Access towers	EL, IT
Access node hardware	
Access node software	NO
Microwave tower	NO
Microwave equipment	
Optical fibre cables and civil infrastructure	IT
Optical fibre active equipment	ES, NO, SI
IP switching	
Core buildings	HR, SI
Core equipment hardware	
Core equipment software	
700 MHz spectrum license	ES
800 MHz spectrum license	
900 MHz spectrum license	CZ
1400 MHz spectrum license	
1800 MHz spectrum license	
2100 MHz spectrum license	MT
2600 MHz FDD spectrum license	
2600 MHz TDD spectrum license	CZ
3400-3800 MHz spectrum license	

Asset category	Outliers
26 GHz spectrum license	

Table 3.70: Useful lives – Data validation [Source: Axon Consulting]

3.1.12.3. Input definition

The average of the validated references for each asset category was calculated to determine the useful life input to be considered in the model, with the exception of spectrum concession periods, which are set at a country level based on the information reported by stakeholders.

The table below shows how each asset category was linked to each resource in the model:

Resource category from the Form	Resource variable from the model
Network elements for which the useful life has been considered as an EEA average	
Access towers	Site.Tower-Rural.# of sites
Access towers	Site.Rooftop-Rural.# of sites
Access towers	Site.Tower-Suburban.# of sites
Access towers	Site.Rooftop-Suburban.# of sites
Access towers	Site.Tower-Urban.# of sites
Access towers	Site.Rooftop-Urban.# of sites
Access node hardware	SingleRAN site equipment.Cabinet.# of Cabinets
Access node software	SingleRAN site equipment.2G Cards.# of Cards
Access node software	SingleRAN site equipment.3G Cards.# of Cards
Access node software	SingleRAN site equipment.4G Cards.# of Cards
Access node software	SingleRAN site equipment.5G Cards.# of Cards
Microwave equipment	Backhaul MW.MWL ETH 100.# of links
Microwave equipment	Backhaul MW.MWL ETH 500.# of links
Microwave equipment	Backhaul MW.MWL ETH 1000.# of links
Microwave tower	Backhaul MW.Tower.# of towers
Optical fibre cables and civil infrastructure	Backhaul DF.DF 160000.lines
Optical fibre cables and civil infrastructure	Backhaul DF.DF 80000.lines
Optical fibre cables and civil infrastructure	Backhaul DF.DF 40000.lines
Optical fibre cables and civil infrastructure	Backhaul DF.DF 20000.lines
Optical fibre cables and civil infrastructure	Backhaul DF.DF 10000.lines
Optical fibre cables and civil infrastructure	Backhaul DF.DF 1000.lines
Optical fibre cables and civil infrastructure	Backhaul DF.DF 100.lines
Optical fibre cables and civil infrastructure	Backhaul DF.DF.length
Core equipment hardware	2G BSC.BSC.# of BSCs
Core equipment software	2G BSC.BSC-SW.# of BSCs-SW
Core equipment hardware	3G RNC.RNC .# of RNCs
Core equipment software	3G RNC.RNC – SW.# of RNCs-SW
Optical fibre active equipment	Backbone DF.DF.lines
Optical fibre active equipment	Backbone DF.80 Gbps.# of ports
Optical fibre active equipment	Backbone DF.40 Gbps.# of ports
Optical fibre active equipment	Backbone DF.20 Gbps.# of ports

Resource category from the Form	Resource variable from the model
Optical fibre active equipment	Backbone DF.10 Gbps.# of ports
Optical fibre active equipment	Backbone DF.1 Gbps.# of ports
Optical fibre cables and civil infrastructure	Backbone DF.DF.length
Microwave equipment	Backbone MW.MWL ETH 100.# of links
Microwave equipment	Backbone MW.MWL ETH 500.# of links
Microwave equipment	Backbone MW.MWL ETH 1000.# of links
Microwave tower	Backbone MW.Tower.# of towers
Core equipment hardware	Core.MGW.# of MGW
Core equipment software	Core.MGW-SW.# of MGW-SW
Core equipment hardware	Core.MSCS.# of MSCSs
Core equipment software	Core.MSCS-SW.# of MSCSs-SW
Core equipment hardware	Core.SGSN.# of SGSN
Core equipment software	Core.SGSN-SW.# of SGSN-SW
Core equipment hardware	Core.GGSN.# of GGSN
Core equipment software	Core.GGSN-SW.# of GGSN-SW
Core equipment hardware	Core.HLR.# of HLR
Core equipment software	Core.HLR-SW.# of HLR-SW
Core equipment hardware	Core.BC .# of BC
Core equipment software	Core.BC -SW.# of BC-SW
Core equipment hardware	Core.SMSC.# of SMSC
Core equipment software	Core.SMSC-SW.# of SMSC-SW
Core equipment hardware	Core.MME.# of MME
Core equipment software	Core.MME-SW.# of MME-SW
Core equipment hardware	Core.SGW.# of SGW
Core equipment software	Core.SGW-SW.# of SGW-SW
Core equipment hardware	Core.PGW.# of PGW
Core equipment software	Core.PGW-SW.# of PGW-SW
Core equipment hardware	Core.PCRF.# of PCRF
Core equipment software	Core.PCRF-SW.# of PCRF-SW
Core equipment hardware	Core.HSS.# of HSS
Core equipment software	Core.HSS-SW.# of HSS-SW
Core equipment hardware	Core.CSCF.# of CSCF

Resource category from the Form	Resource variable from the model
Core equipment software	Core.CSCF-SW.# of CSCF-SW
Core equipment hardware	Core.SBC.# of SBC
Core equipment software	Core.SBC-SW.# of SBC-SW
Core equipment hardware	Core.VoLTE platforms.# of VoLTEs-HW
Core equipment software	Core.VoLTE platforms.# of VoLTEs-SW
Microwave tower	Backhaul HUB.Hub.# of Hubs
Access node hardware	Small cell.Active unit.# of small cells
Access towers	Small cell.Infrastructure element.# of small cells
Average of 'Microwave equipment' and 'Optical fibre cables and civil infrastructure'	Small cell.Backhauling connection.# of small cells
Core equipment software	Core.5G Core equipment.# of Mbps
Network elements for which the useful life has been considered to be country specific	
700 MHz spectrum license	LIC.Licence 700 FDD.MHz
800 MHz spectrum license	LIC.Licence 800 FDD.MHz
900 MHz spectrum license	LIC.Licence 900 FDD.MHz
1800 MHz spectrum license	LIC.Licence 1800 FDD.MHz
2100 MHz spectrum license	LIC.Licence 2100 FDD.MHz
2600 MHz FDD spectrum license	LIC.Licence 2600 FDD.MHz
2600 MHz TDD spectrum license	LIC.Licence 2600 TDD.MHz
3400-3800 MHz spectrum license	LIC.Licence 3400-3800 TDD.MHz
26 GHz spectrum license	LIC.Licence 26000 TDD.MHz

Table 3.71: Useful lives –Input definition – Mapping of asset references [Source: Axon Consulting]

Finally, the table below summarises the list of countries for which spectrum concession periods were set at country level or as an EEA average[36]:

Resource category	Country specific	EEA average
LIC.Licence 700 FDD.MHz	AT, BE, BG, HR, CY, CZ, DK, FR, DE, EL, HU, NO, PT, RO, SK, SI, ES	IE, IT, LU, MT, PL, SE

[36] Note that EEA averages have only been used for this input when no data was reported in the data collection process.

Resource category	Country specific	EEA average
LIC.Licence 800 FDD.MHz	AT, BE, BG, HR, CY, CZ, DK, FR, DE, EL, HU, MT, NO, PT, RO, SK, SI, ES	IE, IT, LU, PL, SE
LIC.Licence 900 FDD.MHz	AT, BE, BG, HR, CY, CZ, DK, FR, DE, EL, HU, MT, NO, PT, RO, SK, SI, ES	IE, IT, LU, PL, SE
LIC.Licence 1800 FDD.MHz	AT, BE, BG, HR, CY, CZ, DK, FR, DE, EL, HU, MT, NO, PT, RO, SK, SI, ES	IE, IT, LU, PL, SE
LIC.Licence 2100 FDD.MHz	AT, BE, BG, HR, CY, CZ, DK, FR, DE, HU, MT, NO, PT, SK, SI, ES	EL, IE, IT, LU, PL, RO, SE
LIC.Licence 2600 FDD.MHz	BE, BG, HR, CY, CZ, FR, DE, EL, HU, MT, NO, PT, RO, SK, SI, ES	AT, DK, IE, IT, LU, PL, SE
LIC.Licence 2600 TDD.MHz	BE, BG, CY, CZ, DE, EL, HU, MT, NO, PT, RO, SK, SI, ES	AT, HR, DK, FR, IE, IT, LU, PL, SE
LIC.Licence 3400-3800 TDD.MHz	AT, BE, BG, HR, CY, CZ, DK, FR, DE, EL, HU, MT, NO, PT, SK, SI, ES	IE, IT, LU, PL, RO, SE
LIC.Licence 26000 TDD.MHz	BG, HR, DK, EL, MT, NO, SI, ES	AT, BE, CY, CZ, FR, DE, HU, IE, IT, LU, PL, PT, RO, SK, SE

Table 3.72: Useful lives –Input definition – Source of the useful lives defined for spectrum elements in the cost model [Source: Axon Consulting]

3.1.13. WACC

In regulatory accounting, the Weighted Average Cost of Capital ('WACC') is the return allowed on the companies regulated activities, calculated weighting the return to each of the company's financing sources: equity and debt. WACC is widely used in the telecoms industry by regulators and operators for several different commercial, financial, technical and regulatory processes.

This input is defined at a country level and is a key element of the calculation of the economic depreciation.

The WACC inputs defined are included in worksheet '2H INP WACC' of the model.

3.1.13.1. Sources of information

The source of information to define the WACC per country was the data provided by the NRAs. The tables below indicate the availability and confidentiality of the data reported by NRAs.

Data availability:

Status	Countries
Complete information	BE, CY, CZ, DE, DK, EL, ES, FR, HR, HU, IE, IT, LU, MT, NO, PL, PT, RO, SI, SE, SK
Not all information provided	AT, BG

Table 3.73: WACC – Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	AT, BE, CY, CZ, DE, DK, ES, FR, HR, HU, IE, IT, MT, SI, SE, SK
Confidentiality level 1	LU
Confidentiality level 2	BG

Table 3.74: WACC – Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.13.2. Input validation and treatment

Given that the model works in nominal currency terms, it was necessary to state all the WACC references received in nominal terms. The conversion from a real WACC to a nominal WACC was performed using the Fisher equation indicated below and the Consumer Price Index (CPI) applicable in each country, as reported by the IMF:

$$WACC_{Nominal} = WACC_{Real} \cdot (1 + CPI) + CPI$$

This conversion from real to nominal WACC was only performed for AT[37].

Once all the WACC references were expressed in nominal terms, the following validation analyses were performed:

- *Reasonability of WACC figures*: The nominal WACC references per country were analysed to identify any potential unreasonable figures. Based on the WACC rates typically considered by NRAs across Europe, any WACC between 3.5% and 10% was considered reasonable. No values were identified outside this range and, therefore, no issues were detected.
- *Consistency across EEA references*: The values provided by NRAs were compared against each other to identify potential discrepancies between them. Specifically, references situated outside a ±50% range from the EEA average were classified as outliers. No values were identified outside this range and, therefore, no issues were detected.

3.1.13.3. Input definition

The nominal WACC considered at country level was extracted from the treated and validated inputs, per country, obtained as a result of the exercises described in section above.

[37] For the calculation, the CPI was assumed as the average inflation forecasted by the IMF for the period 2023-2028.

3.1.14. Wholesale specific costs

This section outlines the treatment given to the wholesale specific costs MNOs need to incur to provide services that involve third-party operators. This involves both wholesale and a number of retail[38] services.

Equivalently to the approach adopted in the previous cost study, these costs were set across EEA countries through a regression analysis that considers fixed and variable price components. The cost categories considered and requested to stakeholders through the Data Request Form are:

- Route testing/monitoring and opening costs
- Operation and management
- Data clearing costs
- Financial clearing costs
- Negotiation and contract management/regulation costs

The wholesale specific costs inputs are introduced in worksheet '2J INP SERVICE SPEC COSTS' of the model.

3.1.14.1. Sources of information

All information used to assess wholesale specific costs was based on information reported by the NRAs.

Additionally, in order to perform the regressions, the following information was also employed:

- Traffic demand (obtained as indicated in section 3.1.2).
- Traffic statistics provided by the NRAs.
- Standard industry values, such as the size of an SMS, the number of MB in a GB or the voice call bitrate (obtained as indicated in section 3.3).

Finally, Euro/European Currency Unit (ECU) exchange rates reported by Eurostat were used to convert unit prices reported in local currencies to Euros.

[38] For instance, voice off-net calls to other national operators.

The tables below indicate the availability and confidentiality of the wholesale specific costs information per country reported by NRAs.

Data availability:

Status	Countries
Complete information	
High-priority information provided	
Not all High-priority information provided	BE, BG, CZ, DE, EL, ES, FR, HR, HU, IE, IT, LU, MT, NO, PL, PT, RO, SI, SK
No information	AT, DK, SE

Table 3.75: Wholesale specific costs – Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	DE
Confidentiality level 1	LU
Confidentiality level 2	BE, BG, CZ, EL, ES, FR, HR, HU, IE, IT, MT, NO, PL, PT, RO, SI, SK

Table 3.76: Wholesale specific costs - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the non-confidential version of the model shared with NRAs.

3.1.14.2. Input validation and treatment

In order to ensure that the references received were comparable to each other, the cost references received were converted to EUR with the exchange rates reported by Eurostat.

On the other hand, in terms of data validation, given the particularities of the approach adopted to define the wholesale specific costs (by means of a regression analysis), the validation performed is described in the 'inputs definition' section below.

3.1.14.3. Input definition

As explained, wholesale specific costs were defined by means of a regression curve including a fixed and a variable cost component for each of the CapEx and OpEx.

The Data Request Form sought to gather cost information for each cost category disaggregated by service type (National interconnection, International interconnection, EU/EEA roaming, Non EU/EEA roaming, Other wholesale national and Other wholesale international). However, many of the references received did not include such split per service type and, when splits were provided, these were typically too simplistically produced. Consequently, the cost assessment was performed at cost category level, without considering the split per service type reported by some stakeholders.

Based on these cost references, linear regressions were defined separately for each cost category. These regressions define the relationship between the costs of each cost category as reported by MNOs and a traffic/volume element. Particularly, for each cost category, the regression drivers were defined consistently with the previous cost study, namely:

Cost category	Traffic/volume elements
Route testing/monitoring and opening costs	GB
Operation and management	TAPs (Transferred Account Procedure)
Data clearing costs	TAPs (Transferred Account Procedure)
Financial clearing costs	TAPs (Transferred Account Procedure)
Negotiation and contract management/regulation costs	GB

Table 3.77: Traffic/volume elements drivers selected to perform the regressions for each cost category [Source: Axon Consulting from drivers defined in studies SMART 2015/0006 and SMART 2017/0091]

Once these relationships were defined, the following steps were adopted to determine the final input values to be included in the model.

- Step 1: Conversion of traffic to GB and TAPs
- Step 2: Consolidation of the costs reported by operators
- Step 3: Rejection of outlier values
- Step 4: Cost analysis and linear regression

Step 1: Conversion of traffic to GB and TAPs

In order to use GBs and TAPs as the selected regression drivers, services' demand (in terms of minutes, SMSs or MB) needs to be converted into these units. The conversion factors considered are presented below for each service category:

- Conversion of data traffic to GB and TAPs
- Conversion of voice traffic to GB and TAPs
- Conversion of SMS to GB and TAPs

Conversion of data traffic to GB and TAPs

The conversion of data services' demand (expressed in MB) into GB and TAPs was performed based on the following considerations:

- *Conversion to GB*: Data is already included in the cost model in MB. To convert MB into GB a division factor of 1,024 was considered.
- *Conversion to TAPs*: A TAP record is generated for each data session. Therefore, the number of TAP records generated depends on the traffic, measured in MB and the average size of a data session (measured in MB per session). The average data session is 41.37 MB/session, therefore, we considered that 1 MB of data traffic generates 1/41.37=0.024 TAPs.

The demand of the following data services for the year 2022 was considered in the calculation of the equivalent demand in terms of GB and TAPs per operator:

- Data Roaming (EEA)
- Data Roaming (Non-EEA)

Given that costs are reported at operator level, the market demand reported by NRAs was multiplied by the market share of each MNO to calculate their traffic in GB and TAPs.

Conversion of voice traffic to GB and TAPs

The conversion of voice traffic (in minutes) into GB and TAPs was performed based on the following considerations:

- *Conversion to GB*: Voice traffic in a circuit switched network circulates at a bitrate of 64 kbps. Considering this bitrate, the number of GB generated by one voice minute are calculated as follows:

$$CF(min\ to\ GB) = \frac{Bitrate\ (kbps) \cdot Seconds/min \cdot bps/kbps}{Bits\ in\ a\ byte \cdot Bytes\ in\ a\ GB} = \frac{64 \cdot 60 \cdot 1000}{8 \cdot 2^{30}} = 0.000447\ GB/min$$

- *Conversion to TAPs*: A TAP record is generated for each voice call. Thus, the number of TAPs generated by a voice minute is obtained as 1 divided by the average call duration. This input was defined on a country-basis to understand the country-specific voice traffic consumption patterns, as described in Section 3.1.3.

The demand of the following voice services for the year 2022 was considered in the calculation of the equivalent demand in terms of GB and TAPs per operator:

- Voice Roaming incoming (EEA)
- Voice Roaming outgoing (EEA)
- Voice Roaming incoming (Non-EEA)
- Voice Roaming outgoing (Non-EEA)
- Voice Domestic incoming from national
- Voice Domestic incoming from international
- Voice Domestic off-net to national

Given that costs are reported at operator level, the market demand reported by NRAs was multiplied by the market share of each MNO to calculate their traffic in GB and TAPs.

Conversion of SMS to GB and TAPs

The conversion of SMS traffic into GB and TAPs was performed based on the following considerations:

- *Conversion to GB*: The conversion of SMS to GB is based on the average size of an SMS, which has been considered to be 125 bytes per SMS[39]. Therefore, the number of GB generated by an SMS was obtained by dividing the size of an SMS (125 Bytes) by the number of Bytes in a GB (2^{30}).
- *Conversion to TAPs*: A TAP record is generated for each SMS. Therefore, the number of TAPs is equal to the number of SMS.

[39] The exchange of short messages between the SMSC and the user equipment is limited at 140 bytes per message when using the Mobile Application Part (MAP) of the SS7 protocol. This limitation is the reasoning behind the typical 160-character limit in SMS, given that GSM uses a 7-bit alphabet to codify these messages. Given that not all SMS are 160-character long, defining an average SMS size below 140 bytes is recommended.

The demand of the following SMS services for the year 2022 was considered in the calculation of the equivalent demand in terms of GB and TAPs per operator:

- SMS Roaming incoming (EEA)
- SMS Roaming outgoing (EEA)
- SMS Roaming incoming (Non-EEA)
- SMS Roaming outgoing (Non-EEA)
- SMS Domestic incoming from national
- SMS Domestic incoming from international
- SMS Domestic off-net to national

Given that costs were reported at operator level, the market demand reported by NRAs was multiplied by the market share of each MNO to calculate their traffic in GB and TAPs.

Step 2: Consolidation of the costs reported by operators

As previously explained, the cost splits per service type reported by stakeholders was not deemed to be complete and robust enough to be considered as an input for our analysis. Therefore, the cost split reported by stakeholders (when they included such splits) was added up to assess the total costs per operator and cost category.

Step 3: Rejection of outlier values

Once the costs and the traffic drivers to be used to build up the regressions were thoroughly defined, outliers were identified and rejected to avoid distorting the trends.

Pairs of costs-drivers were discarded when, once pictured in a graph, these were found to be outside the reasonable range/trend exhibited by other peers. The table below illustrates the number of references collected for each cost category, indicating the number of values that were accepted/rejected in each case:

Cost category	Cost Type	Values reported	Rejected values	Accepted values
Route testing/monitoring and opening costs	OPEX	22	10	**12**
	CAPEX	10	N/A	N/A
Operation and management	OPEX	26	11	**15**
	CAPEX	5	N/A	N/A
Data clearing costs	OPEX	28	8	**20**
	CAPEX	3	N/A	N/A
Financial clearing costs	OPEX	21	12	**9**
	CAPEX	2	N/A	N/A
Negotiation and contract management/regulation costs	OPEX	27	9	**18**
	CAPEX	3	N/A	N/A

Table 3.78: Values reported and outliers for each cost category [Source: Axon Consulting based on data reported by stakeholders]

For the sake of consistency with the previous cost studies (SMART 2015/0006 and SMART 2017/0091), only the following cost categories were considered in the model:

- Route testing/monitoring and opening costs - OPEX
- Operation and management – OPEX
- Data clearing costs - OPEX
- Financial clearing costs - OPEX
- Negotiation and contract management/regulation costs - OPEX

Moreover, it should be mentioned that, in the current assignment CNECT/2022/OP/0065, the 'Operation and management – CAPEX' category, which had been included in the previous cost studies, was discarded as the limited number of references reported was not enough to develop a robust linear regression. This is consistent with the situation observed in the table above, which shows that a limited number of references were collected for CapEx related items, reinforcing the conclusion reached in the previous cost study that CapEx costs are negligible.

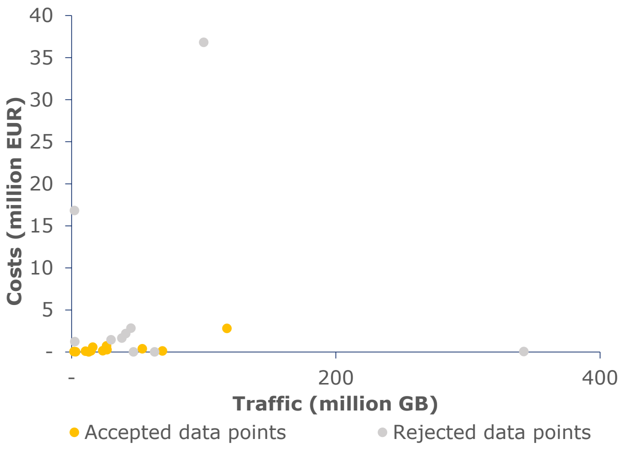
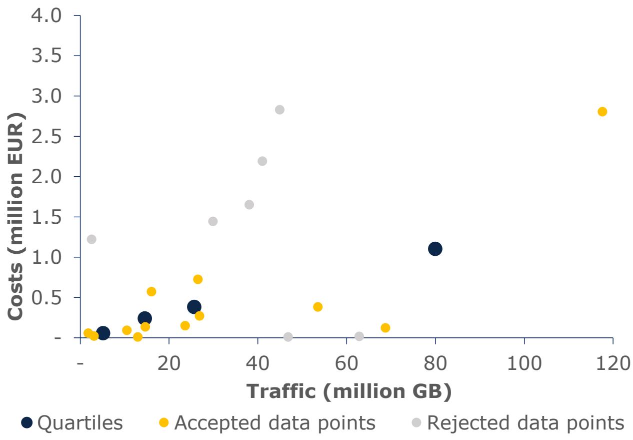
Step 4: Cost analysis and linear regression

As stated throughout this section, the values to be included in the cost model were extracted from a series of regression analyses for each cost category. This analysis provides the model with a) a fixed cost and b) a variable cost based on traffic.

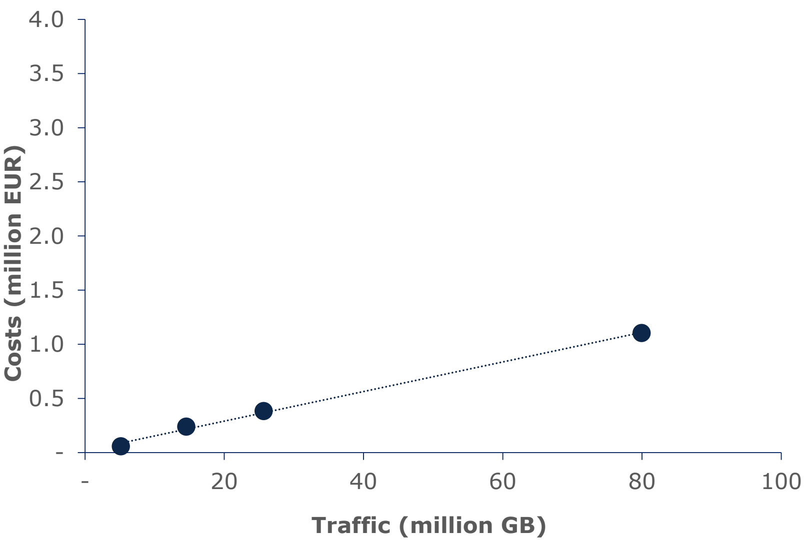
A linear regression model was developed consistently with the methodology adopted in the previous cost studies. Given the disparity of the references observed for several cost categories, it was complex to identify relevant cost trends where all the references were considered at the same time. Consequently, references were presented in quartiles to better identify the common patterns registered in the different groups of operators. The following tables provide a detailed overview of the results obtained for each cost category.

Cost category	ROUTE TESTING/MONITORING AND OPENING COSTS
Cost type	OpEx

Overview of the references observed

All references	Zoom into the most populated range
	

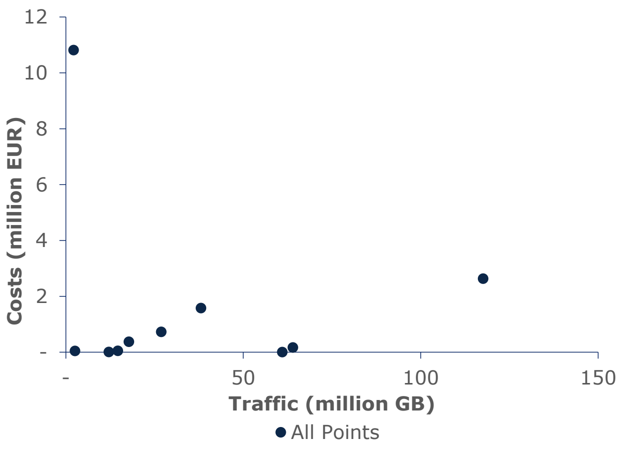
Linear regression based on quartiles



Regression formula	Y = 0.0137x + 17,124

Cost category	ROUTE TESTING/MONITORING AND OPENING COSTS
Cost type	CapEx

Overview of the references observed

All references	Zoom into the most populated range
	N/A

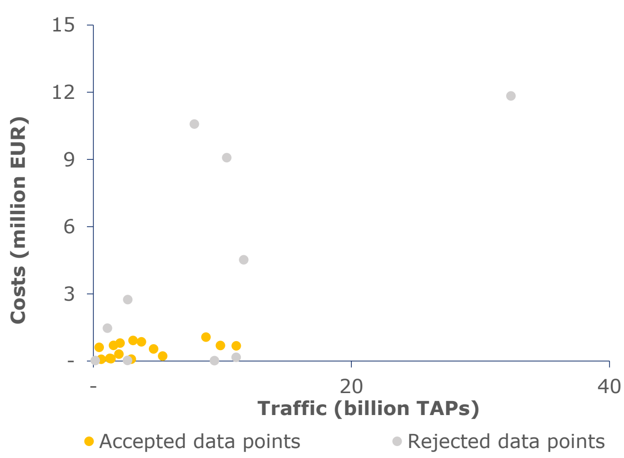
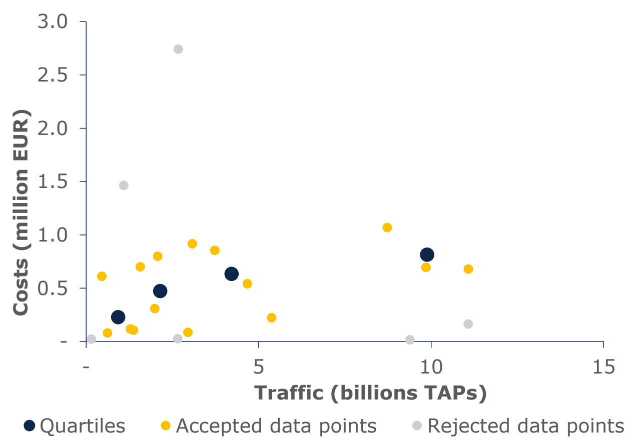
Linear regression based on quartiles

N/A

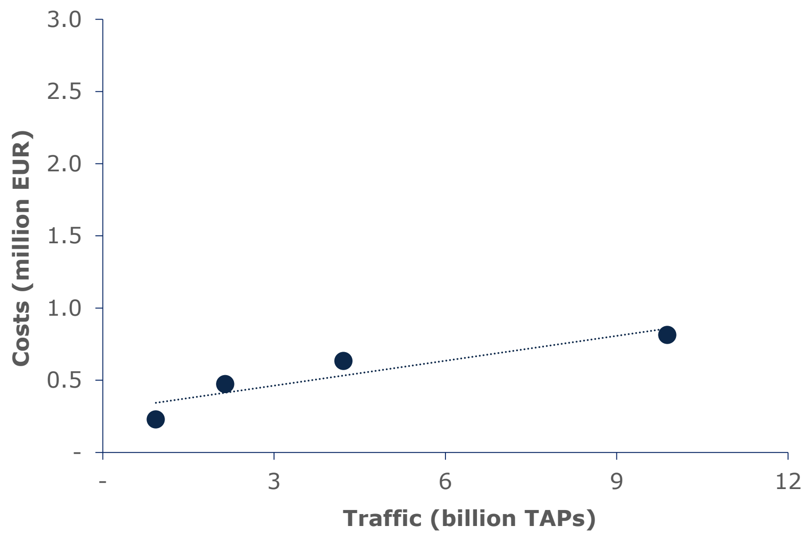
Regression formula	N/A

Cost category	OPERATION AND MANAGEMENT
Cost type	OpEx

Overview of the references observed

All references	Zoom into the most populated range
	

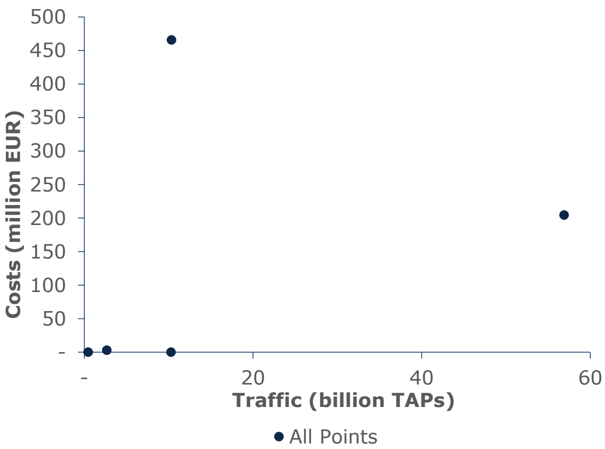
Linear regression based on quartiles



Regression formula	$Y = 6 \cdot 10^{-5}x + 289{,}925$

Cost category	OPERATION AND MANAGEMENT
Cost type	CapEx

Overview of the references observed

All references	Zoom into the most populated range
	N/A

Linear regression based on quartiles

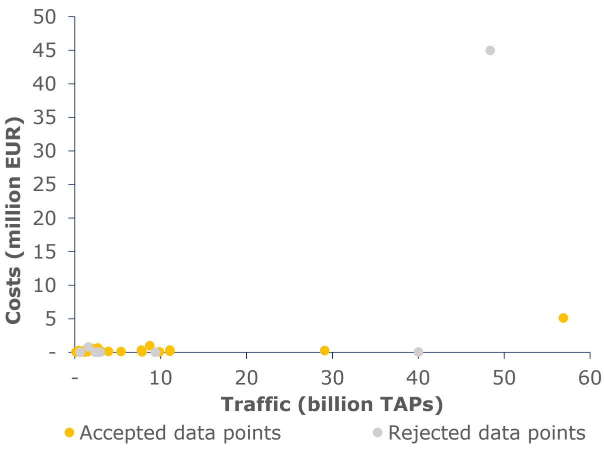
N/A

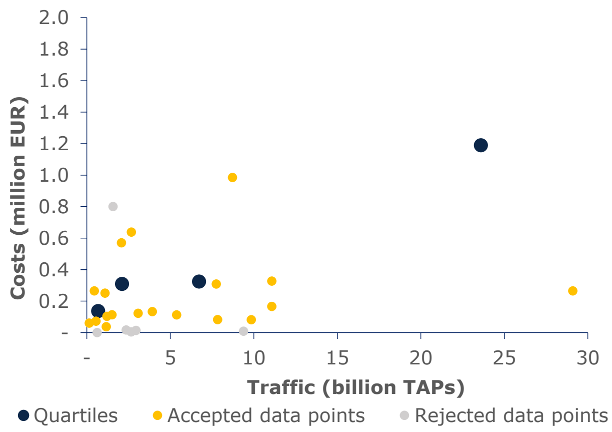
Regression formula	N/A

Cost category	DATA CLEARING COSTS
Cost type	OpEx

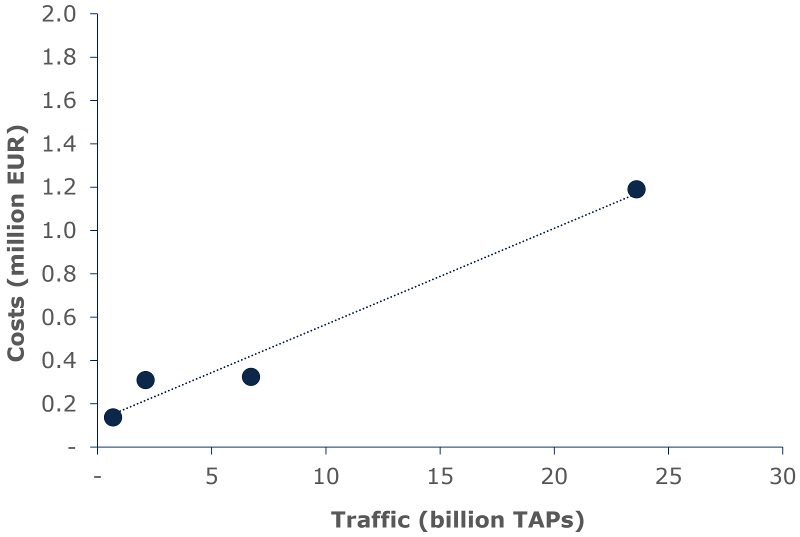
Overview of the references observed

All references	Zoom into the most populated range





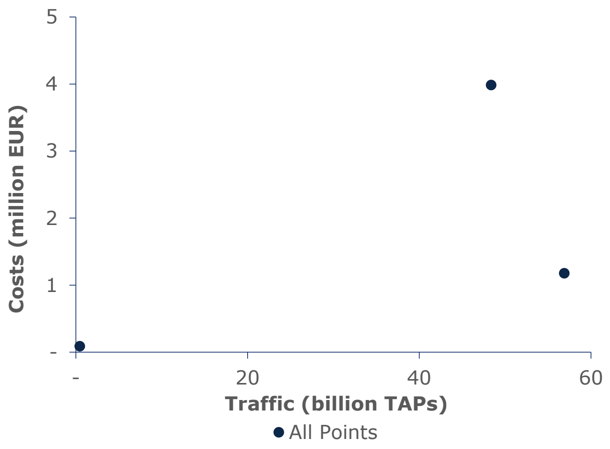
Linear regression based on quartiles



Regression formula	$Y= 4\cdot10^{-5}x + 122,462$

Cost category	DATA CLEARING COSTS
Cost type	CapEx

Overview of the references observed

All references	Zoom into the most populated range
	N/A

Linear regression based on quartiles

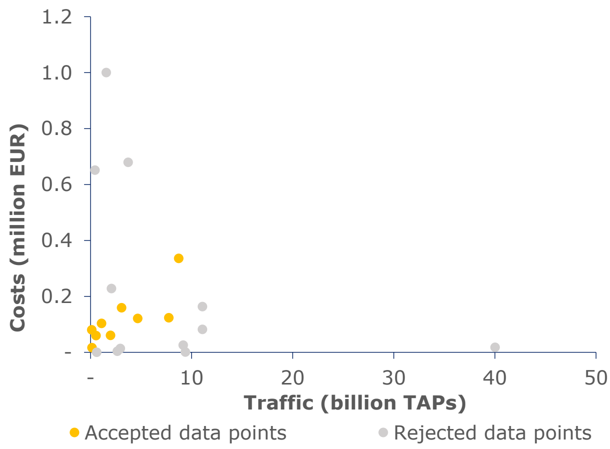
N/A

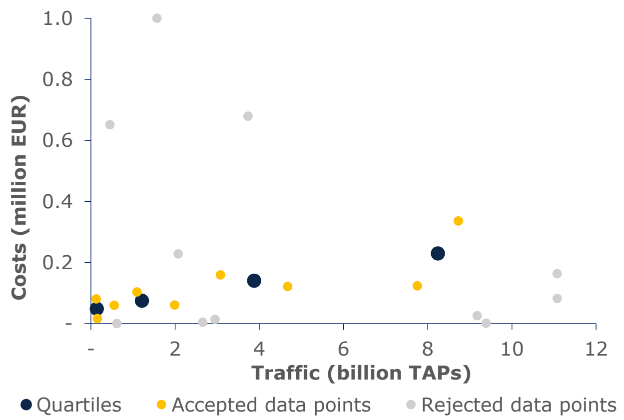
Regression formula	N/A

Cost category	FINANCIAL CLEARING COSTS
Cost type	OpEx

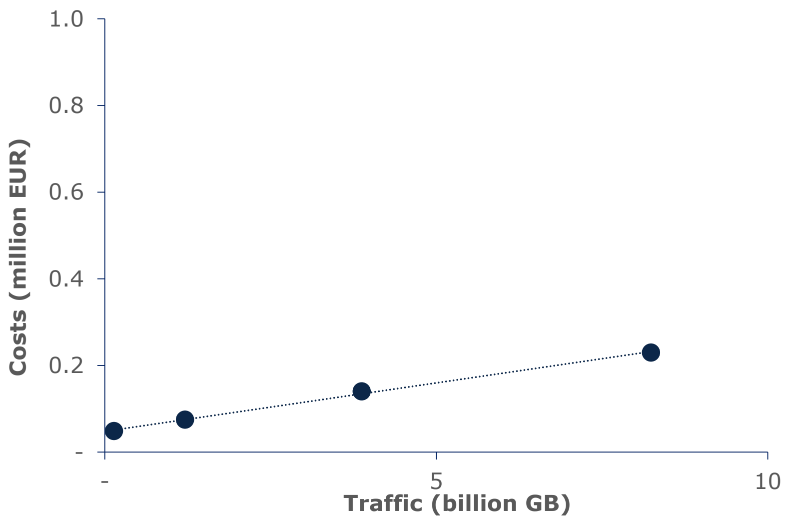
Overview of the references observed

All references	Zoom into the most populated range





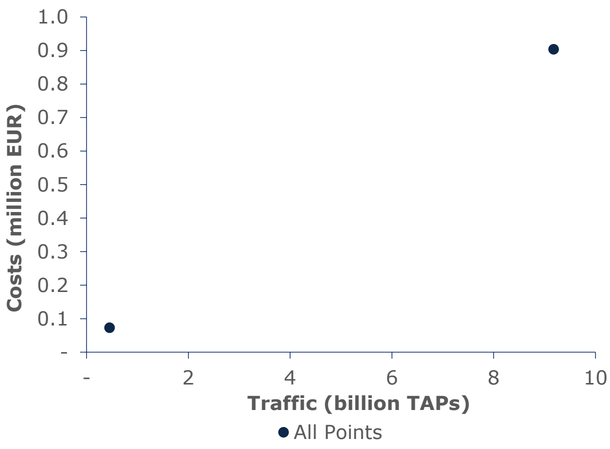
Linear regression based on quartiles



Regression formula	$Y = 2 \cdot 10^{-5}x + 48{,}000$

Cost category	FINANCIAL CLEARING COSTS
Cost type	CapEx

Overview of the references observed

All references	Zoom into the most populated range
	N/A

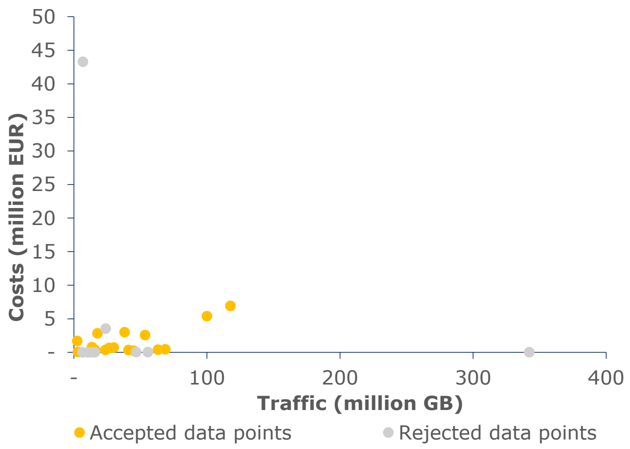
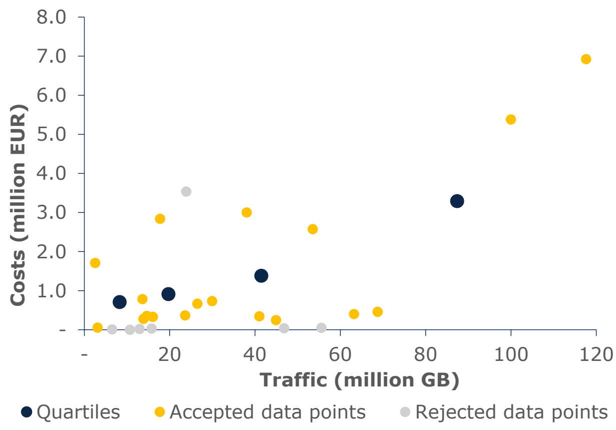
Linear regression based on quartiles

N/A

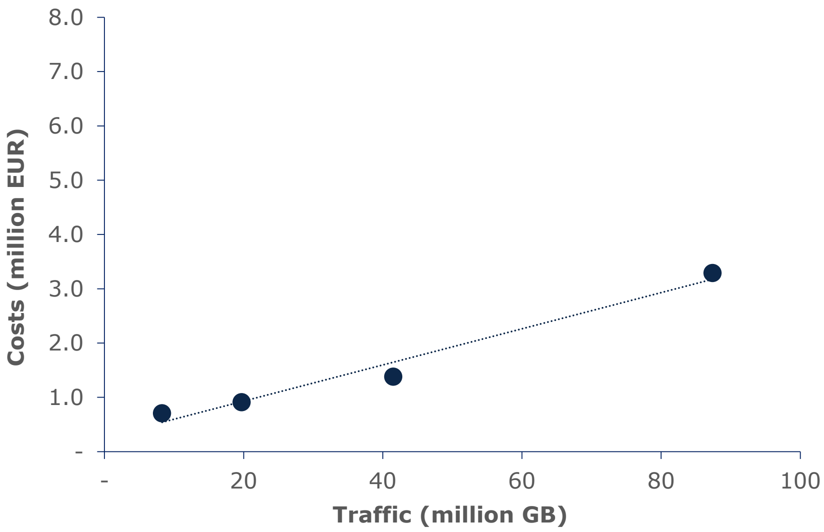
Regression formula	N/A

Cost category	NEGOTIATION AND CONTRACT MANAGEMENT/REGULATION COSTS
Cost type	OpEx

Overview of the references observed

All references	Zoom into the most populated range
	

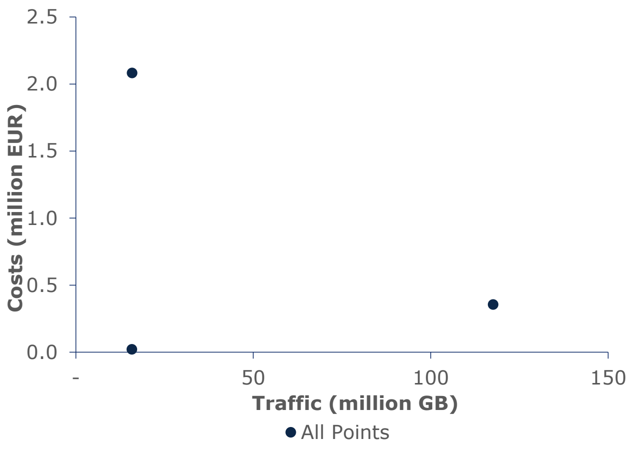
Linear regression based on quartiles



Regression formula	Y= 0.0333x + 264,724

Cost category	NEGOTIATION AND CONTRACT MANAGEMENT/REGULATION COSTS
Cost type	CapEx

Overview of the references observed

All references	Zoom into the most populated range
	N/A

Linear regression based on quartiles

N/A

Regression formula	N/A

3.2. Geographical inputs

In cost models of mobile networks, it is particularly important to accurately represent the geographical characteristics and constraints of a country in order to ensure that the modelled network is representative of the country. For instance, densely populated areas or hilly areas will require MNOs to install more equipment to deliver the same quality of service as in other areas with different characteristics.

The geographical analysis performed was aimed at obtaining three key indicators per country, namely:

- *Population and area per geotype:* This information was crucial to characterise the geography and demography of a country. To avoid having to treat each municipality individually in the model, cost models identify geotypes encompassing specific types of municipalities[40]. Geotypes aggregate all municipalities that share similar characteristics in terms of population and density of population.
- *Distribution of population in rural areas:* Population is not evenly distributed across a country. Consequently, it was highly important to understand its distribution (especially in rural areas) to identify the implications of reaching a given percentage of population coverage in terms of area coverage. For instance, it is a common trend that 90% of rural population occupies just 60% of all the rural area of a country.
- *Topography of the terrain:* The analysis of topography deals with the identification of hilly areas. In the cost model, this input was key to characterise the hilliness of the terrain in rural areas so that the network can be dimensioned respecting the topography of each country.

The sections below outline the inputs and methodology considered to calculate each of the three country specific indicators described above.

The geographical analysis inputs are included in the worksheets '2B INP GEO' and '2D INP DIST POP GEOT' of the model.

[40] Modelling at municipality level would have required massive information requirements form the operators and increasing unreasonably the size and complexity of the model. The use of geotypes is broadly extended and the most common approach followed in bottom-up models around the world.

3.2.1. Inputs

The information employed to perform the geographical analysis was extracted from the sources described below:

- **Eurostat**: A key source of information was Eurostat's GISCO[41] database. GISCO is a permanent service that provides geographical information at EEA level, its member states and regions. GISCO assigns degrees of urbanization (DEGURBA)[42] to municipalities across the EEA. For each EEA country, two levels of local administrative units (LAU) are defined, LAU1 and LAU2. Each LAU2 is further classified by GISCO (Local administrative units level 2) into three different categories based on population density – high density clusters, urban clusters and rural clusters -. A description of the process followed by GISCO to classify the municipalities is provided in Annex A. In summary, the main information extracted from GISCO consisted in the DEGURBA database and LAU information.
- **Geographical information from Geonames.org**[43]: The Geonames database includes information of the municipalities from each EEA country (and the rest of the world). The information available includes the name, code, and coordinates of the municipalities of each EEA country.
- **Coordinates information from Google Places API**: Google PLACES API (Application Programming Interface) allows any licensed user to get different sets of information. When the coordinates of a municipality were not available through GISCO or Geonames, Google's APIs were used to identify the location of missing municipalities.

3.2.2. Population and area per geotype

As previously explained, a proper characterisation of the municipalities of a country in terms of area and population was critical to ensure the accuracy of the model. Based on the information available at GISCO, we designed a step by step methodology that was both straightforward and reviewable (see section 3.2.2.1).

[41] Within Eurostat, GISCO is responsible for meeting the geographical needs at three levels: the European Union, its member countries, and its regions - http://ec.europa.eu/eurostat/web/gisco

[42] Eurostat Data base with the degree of urbanization for each municipality: http://ec.europa.eu/eurostat/web/nuts/local-administrative-units

[43] Geonames Data base: http://www.geonames.org/

3.2.2.1. Methodology

This section describes the methodology adopted to calculate the population and area per geotype. This methodology was based on the steps described below:

- Extracting geographical information
  - Step 1: Link geotypes with area and population data
  - Step 2: Extracting municipalities' coordinates
  - Step 3: Ensure representativeness of the municipalities considered
- Dividing the country into samples
  - Step 1: Defining the sample area
  - Step 2: Dividing the countries into samples.
  - Step 3: Assigning the municipalities to samples
- Area and population per geotype

Extracting geographical information

In order to properly dimension the access network in each geotype defined in the model, it was important to extract the key geographical information characterising each geotype. This section describes the steps performed to extract the population and area per municipality and consolidate them at geotype level. It also outlines the approach adopted to extract the coordinates of all the municipalities in each country.

The steps followed to extract the data and to validate that it was representative of each country are described below:

- Step 1: Link geotypes with area and population data
- Step 2: Extracting municipalities' coordinates
- Step 3: Ensure representativeness of the municipalities considered

Step 1: Link geotypes with area and population data

GISCO's database includes information on the degree of urbanisation of municipalities. This information characterises the geotypes these municipalities belong to (URBAN, SUBURBAN or RURAL). However, the database does not include information of the area and population of the municipalities.

Given that this information was essential to produce some ad-hoc analyses at geographical level (seasonality assessment, population distribution pattern in rural areas), we linked the information available in GISCO's database with the LAU information available from Eurostat.

Step 2: Extracting municipalities' coordinates

Having appropriate information about the municipalities' coordinates was essential to assess their topography, among others.

Geonames database provided accurate data of the coordinates for almost all EEA municipalities. In addition, the information included in this database was easy to relate to the area and population data obtained in the first step.

While in most cases this information could be extracted from Geonames, there were approximately 100 municipalities that were not registered in Geonames' database. In these cases, we relied on Google's APIs to identify their coordinates.

Step 3: Ensure representativeness of the municipalities considered

As part of the analysis of the data collected so far, we observed that the LAU2 category employed by Eurostat may have a different definition across EEA countries. In particular, we observed that while it clearly represents municipalities in some countries, in some other countries it reflects higher level administrative regions.

In order to maximise the consistency of the information across countries, the LAU2 information from Eurostat was discarded when the average area of a LAU2 was higher than 200 km^2. We verified on maps that for all the cases in which this condition was fulfilled, the LAU2 information available from Eurostat did not represent municipalities.

The countries for which Eurostat information was discarded are DK, FR and HU. In the cases where the information was discarded, the following steps were followed to obtain the information at municipality level:

- The name, municipality code and coordinates of the municipalities were extracted from Geonames database.
- A degree of urbanization was assigned to each municipality extracted from Geonames. Each geonames' municipality was assigned the geotype of its nearest LAU2.

In these cases, population and area information was not calculated at municipality level. This was not possible based on the data available and it only implied a limitation on the determination of the distribution of population in rural areas (see section 3.2.3). Note, however, that population and area information was indeed available at geotype level (from Eurostat), which constituted the most relevant input required for this geographical analysis.

Dividing the country into samples

Finally, in order to ensure consistency in the treatment of the geographical information across countries, each country was divided in samples (squares with a homogeneous size across a country) with a surface similar to the expected coverage area of a site. The usage of the samples ensures that all the analyses performed in the coming sections are comparable across countries.

This section describes how these samples were defined and obtained and is split as per the three following steps:

- Step 1: Defining the sample area
- Step 2: Dividing the countries into samples.
- Step 3: Assigning the municipalities to samples

Step 1: Defining the sample area

The first step was to define the area of the samples to be considered. Considering an average 6.5Km cell radii for mid-low frequency bands and recognising that the samples to be defined were square, the area of the sample was defined at 132 km^2.

Step 2: Dividing the countries into samples.

The second step consisted in dividing the country into the samples defined in the previous section. Samples were considered to be exclusive, meaning that there was no overlap among them, and they covered the full area of a country.

The exhibit below provides an illustrative overview of the division of a country into samples:

Table 3.79: Geographical inputs – Population and area per geotype – Illustrative example of the division of a country into samples [Source: Axon Consulting]

Step 3: Assigning the municipalities to samples

The main objective of this step was to assign each municipality to a cell in the grid (sample) and to aggregate the information at sample level. To do so, the information of the municipalities that fell within a sample was aggregated.

At the end of this process, we achieved a clear view of the populated samples as well as the total population contained in each of them.

Area and population per geotype

This section explains how the area and population were obtained for each geotype. The population information was obtained from the sum of all the population living in each of the geotypes. On the other hand, the area information was obtained in two different ways, depending on the input:

- *When the input was directly from the Eurostat data*: In this case, the area was the total area provided by Eurostat per geotype. A review was made to ensure that the total area did not exceed the area on the used samples.
- *When the input was extracted from Geonames' info*: In this case, the area was the sum of the samples. A review was made to ensure that total area did not exceed the area on the used samples.

3.2.2.2. Results

Following the steps presented in the sections above, the following information was obtained:

- *Area and population per sample*. This result was not used directly in the model, but it was key to assess the distribution of population in rural areas and assess the topography or the terrain (see sections 3.2.3 and 3.2.4).
- *Area and population per geotype*. This information was directly included in the model to characterise the geotypes in each country. The table below summarises the information obtained for each EEA country.

Country	AREA			POPULATION		
	Urban	Suburban	Rural	Urban	Suburban	Rural
Austria	929	8.787	63.443	3.046.696	2.648.801	3.283.432
Belgium	1.504	14.414	14.611	3.303.446	6.741.843	1.572.334
Bulgaria	2.305	8.108	100.582	2.953.689	1.651.132	2.234.116
Croatia	1.239	10.567	34.550	1.258.733	1.252.567	1.351.005
Cyprus	419	620	5.270	465.246	267.127	172.332
CZ Republic	2.151	10.241	66.479	3.183.554	3.581.699	3.751.454
Denmark	780	13.268	28.877	1.819.434	2.111.170	1.942.816
France	26.164	30.886	492.010	30.978.743	14.781.563	22.111.619
Germany	17.733	112.970	222.681	29.154.561	36.451.022	17.631.541
Greece	3.982	35.963	91.749	5.088.790	2.777.181	2.593.811
Hungary	794	13.725	78.493	3.043.278	3.594.168	3.051.564
Ireland	836	2.400	66.675	1.707.810	1.125.513	2.226.681
Italy	14.789	99.829	186.673	19.750.640	28.655.125	10.624.368
Luxembourg	50	500	2.747	124.894	281.297	239.206
Malta	50	265	-	249.851	271.120	-
Norway	4.553	38.550	271.698	1.541.782	2.148.748	1.734.741
Poland	7.451	47.318	254.300	12.974.122	10.597.892	14.082.233
Portugal	4.362	12.349	72.136	4.528.772	3.272.631	2.550.640
Romania	3.700	31.496	177.749	6.655.054	4.941.479	7.445.922
Spain	25.374	109.718	313.909	25.636.447	15.391.448	6.404.999
Sweden	16.261	144.958	286.205	4.217.351	4.189.892	2.045.083
Slovenia	589	5.140	14.544	432.267	795.989	878.923
Slovakia	1.113	7.077	40.726	1.112.732	2.034.346	2.287.634

Table 3.80: Geographical inputs – Population and area per geotype – Results [Source: Axon Consulting]

3.2.3. Distribution of population in rural areas

Population is not evenly distributed across a geotype. In the case of urban and suburban areas, this situation does not have a relevant impact on the results of the model due to the fact that they are virtually fully covered. In the case of rural areas, which are partially covered, this situation may have a relevant impact in the results. The proper consideration of this factor was essential to understand the implications in terms of area coverage to provide the mobile service to a given percentage of rural population.

The following figure illustrates the typical distribution of population across rural areas analysed in the EEA area. The trend displayed in the figure is far from being linear. Hence, from a coverage deployment perspective, it could be said that omitting the consideration of this factor could significantly overestimate the number of sites required in rural geotypes.

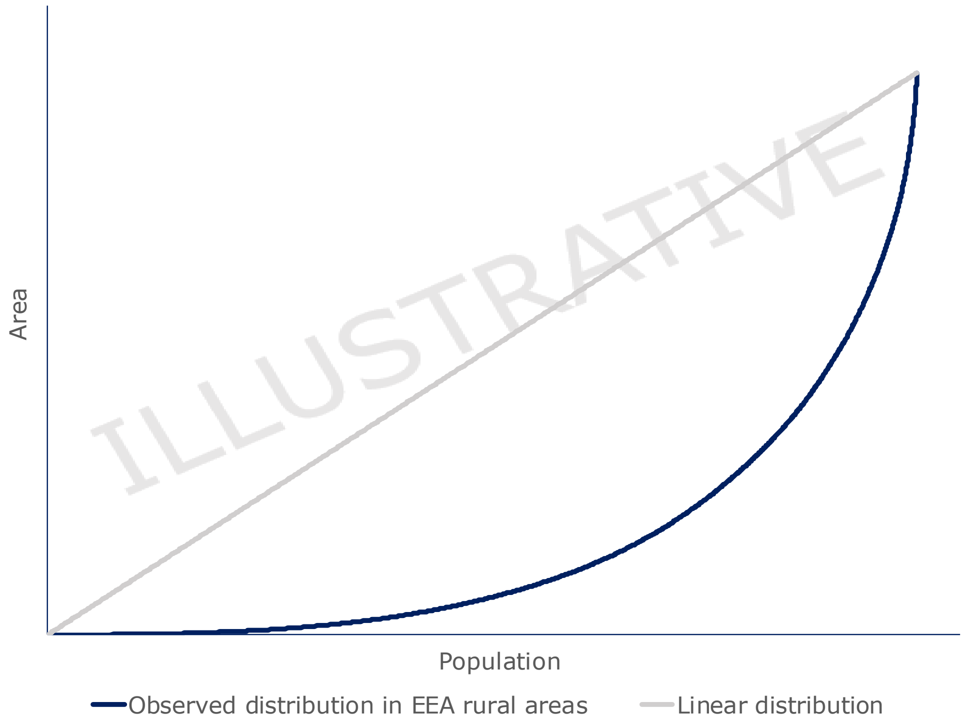


Figure 3.4: Geographical inputs – Distribution of population – Illustrative example of the area and population relationship in rural geotypes [Source: Axon Consulting]

The sections below illustrate the approach adopted to assess how population is distributed in rural areas and the model's inputs that were obtained.

3.2.3.1. Methodology

The methodology adopted to assess the distribution of population in rural areas is presented in this section. The methodology adopted is characterised by the following considerations:

- It is replicable and consistent across all EU/EEA countries.
- Its outcomes are easily manageable.
- Its outcomes are as close to reality as possible.

The methodological approach adopted was based on the following steps, which were performed for each EU/EEA country:

- *Step 1. Rearrange the area and population data per municipality*: Based on the approach described in section 3.2.2, the area and population data per sample were obtained. Knowing this information, it was possible to rearrange it (sorting it from the more densely populated areas to the less densely populated areas) to understand the population distribution in rural areas.
- *Step 2: Express the area and population data per municipality in percentage terms*: While the information produced at the end of step 1 already represented the population distribution in rural areas, it was hardly comparable across countries and difficult to deal with. Accordingly, as part of step 2, the information produced in Step 1 was adjusted to represent it in percentage terms (percentage of population per percentage of area), as illustrated below:

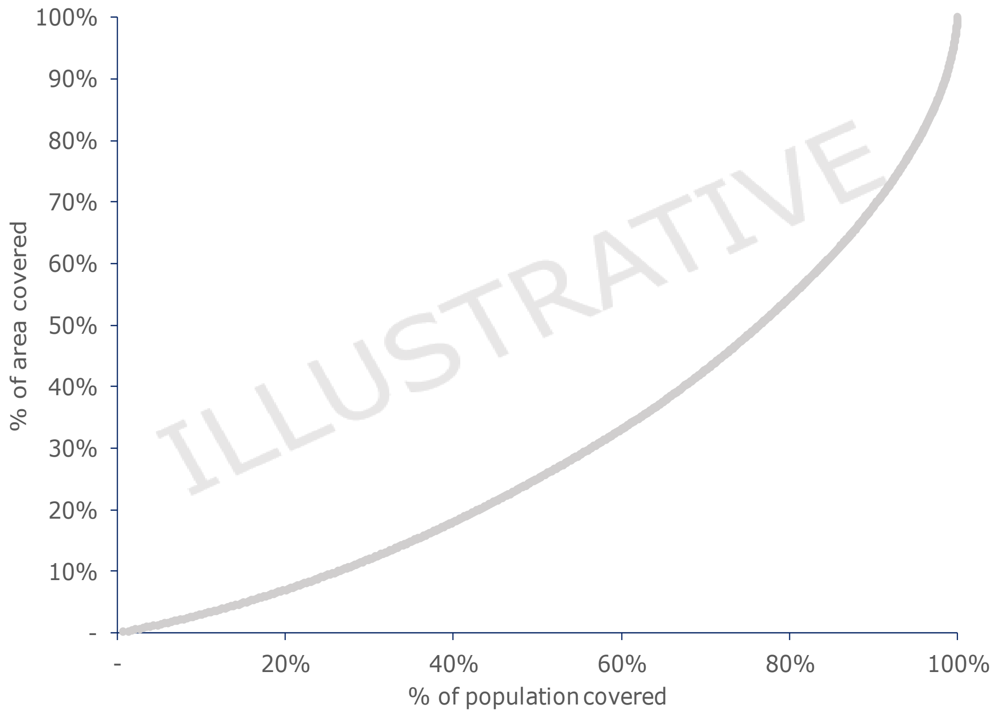


Figure 3.5: Geographical inputs – Distribution of population – Illustrative example of relative area vs population [Source: Axon Consulting]

- *Step 3: Curve fitting:* While the outcomes generated at the end of Step 2 were already comparable across countries, they were still difficult to manage as they included several data points. To make the treatment of this information easier, the population distribution pattern was approximated by a formula. In particular, based on the shape of the population distribution curves shown in the exhibits above, the following formulation represented the observed pattern best:

$$Area\ \% = e^{b \times (Population\% - 1)}$$

Where *b* determines the specific shape/slope of the curve and has been independently calculated for each EU/EEA country.

In order to ensure the representativeness of the regression curve, the b parameter was calculated in a way that minimised the root mean square error (RMSE) between the original curve and the estimated one. The RMSE is defined by the following formula:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (y - \mathrm{e}^{\mathrm{b}(\mathrm{x}-1)})^2}{N}}$$

Where,

- N is the number of rural samples in the country
- x is the real percentage of population covered
- y is the real percentage of area covered
- b is the parameter been estimated

The exhibit below provides an overview of the curve determined through the formula above, compared with the original data presented in Step 2:

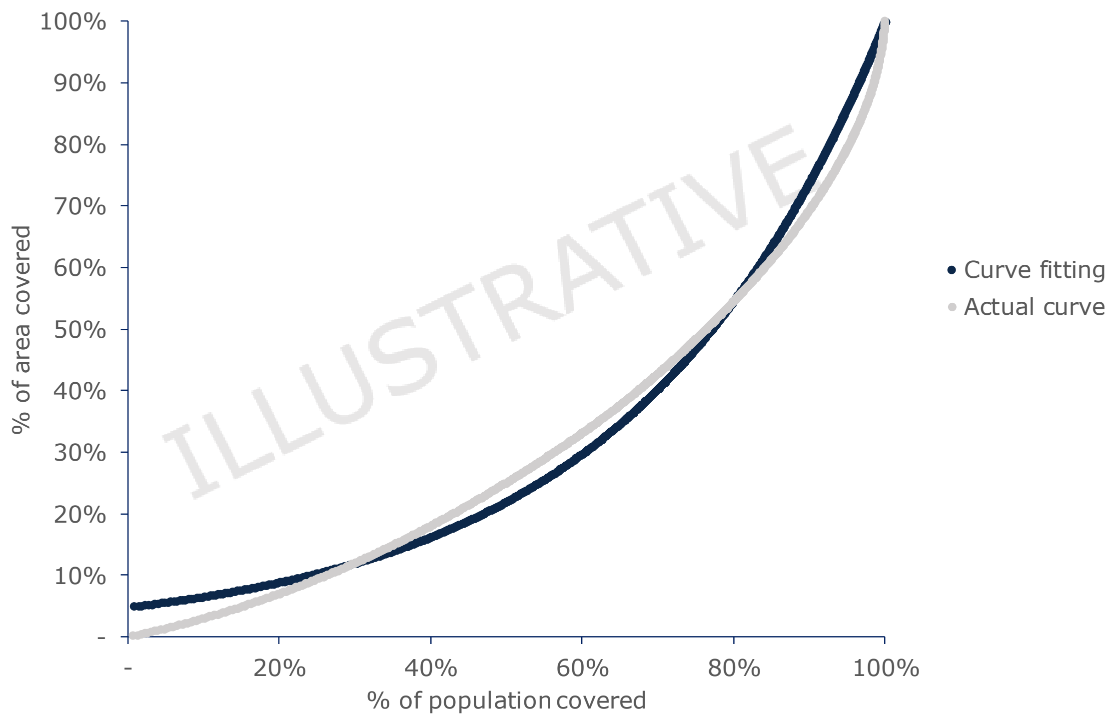


Figure 3.6: Geographical inputs – Distribution of population – Illustrative example of relative area vs population and exponential approximation [Source: Axon Consulting]

- *Step 4 Estimation of information for countries where Geonames was used*: As explained in section 3.2.2.1, the Eurostat data was discarded for some countries where the area of the LAU2 locations was above 200 sq.km. Discarding this data meant that population had to be analysed at geotype level (instead of municipality level) for these countries. In turn, this implied that it was not possible to calculate the population per sample in these countries, which is an essential input to perform this analysis.

  Alternatively, and given the similarity of the references calculated for the countries in which data was available, an EEA average was considered for the countries for which geonames data was used.

3.2.3.2. Results

In this section, the *b* parameter under the $Y= e^{b(x-1)}$ equation is shown for all the countries in the EEA. In the table below, the parameter b is shown along with the Root Mean Square (RMSE).

Country	b	RMSE
Austria	3.19	4.12%
Belgium	2.71	2.41%

Bulgaria	3.78	6.32%
Croatia	3.18	2.52%
Cyprus	3.62	5.68%
Czech Republic	2.95	3.76%
Denmark	3.62	EEA average taken
France	3.62	EEA average taken
Germany	3.03	3.73%
Greece	5.27	7.07%
Hungary	3.62	EEA average taken
Ireland	3.59	5.10%
Italy	3.32	4.87%
Luxembourg	3.62	EEA average taken
Malta	No rural areas	
Norway	3.89	3.60%
Poland	3.62	EEA average taken
Portugal	5.84	2.96%
Romania	2.79	2.65%
Slovakia	3.05	5.03%
Slovenia	3.16	3.24%
Spain	5.17	7.22%
Sweden	3.62	EEA average taken

Table 3.81: Geographical inputs – b and RMSE values for regressions [Source: Axon Consulting]

3.2.4. Topography of the terrain

The topography of the terrain is an important constraint in the access network dimensioning as it can limit the expected reach of the signal. The assessment of topography was not focused on evaluating whether a given sample is more or less elevated from the sea level, but on the unevenness registered in its surroundings.

This analysis was performed only for rural areas, where site deployments could be expected to be more constraint by topography. In the case of urban and suburban areas, given that the number of sites to be deployed typically depends on the capacity they need to handle, their topography was not assessed.

The objective of this analysis was therefore to conclude on the percentage of mountainous[44] rural areas over the total rural areas of the country. The paragraphs below describe the methodology adopted to perform this analysis as well as the outcomes obtained.

3.2.4.1. Methodology

The topography assessment was performed on the rural samples defined in section 3.2.2. For each of these samples, a total of 8 coordinates around its centre point were drawn. According to the size of the sample defined in that section 3.2.2, the points conforming the square were found to be at a distance of between 3.8 km and 5.4 km from the centre of the square. The following exhibit provides an illustrative overview of the definition of these coordinates:

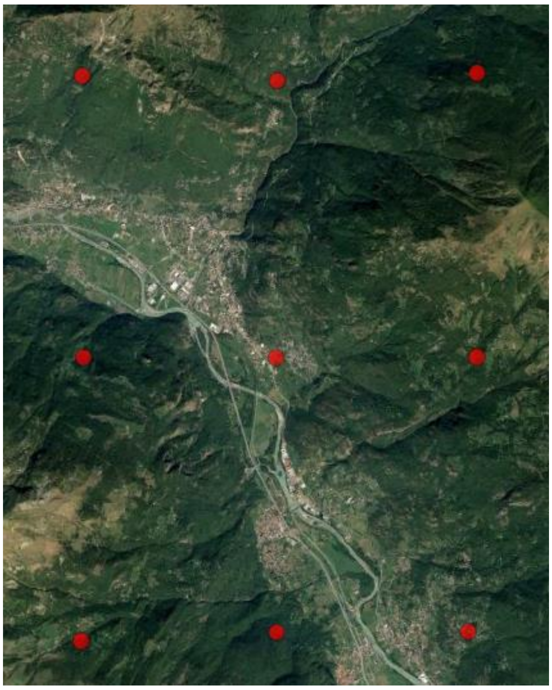


Figure 3.7: Geographical inputs – Topography of the terrain – Points defining the square [Source: Axon Consulting]

For each of these 9 coordinates (including the centre), the elevation information was extracted from Google Elevation API. As a result of this process, the elevation of the 9 coordinates of the sample was determined:

[44] The definition of when a rural area is considered to be mountainous is provided below in the methodology section.

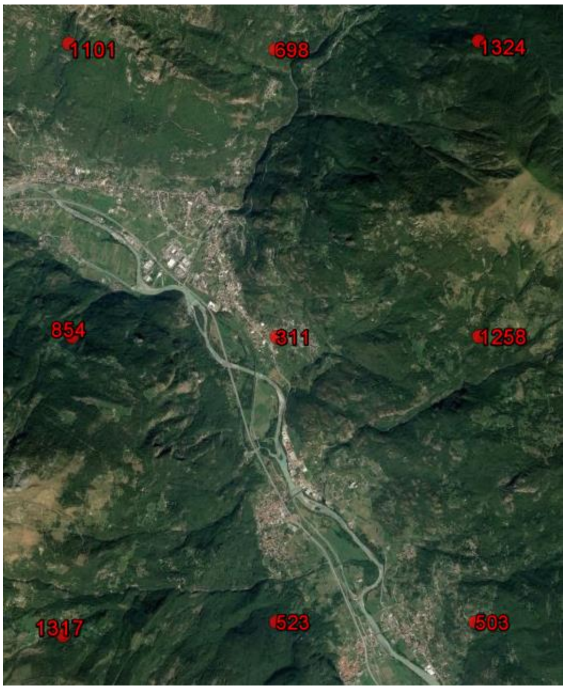


Figure 3.8: Geographical inputs – Topography of the terrain – Height of the points defining the square [Source: Axon Consulting]

Finally, to assess the unevenness of a sample, the difference between the highest and the lowest elevated points was calculated. As per the example shown in the exhibit above, its unevenness would be 1,324 m – 311 m = 1023 m.

After estimating the unevenness of a sample, the next step involved the definition of the characteristics that would make a sample qualify as mountainous. Frequencies between 500MHz and 3800MHz, which include all the frequencies currently in use for the provision of mobile services, are affected by obstacles present between the emitter and the received. Therefore, mountains can drastically affect the propagation characteristics of the signal. Calculating the Fresnel zone[45] clearance of a 900MHz signal, an obstacle higher than 30m at a distance of 1/10th from the sample side would start blocking the signal behind the obstacle. At the same time, an unevenness of 30m at a distance of 1/10th from the sample side would equate to an unevenness of 300m across the sample side. Taking this into consideration, all the samples with an unevenness higher than 300m were considered to be mountainous. As shown below, this meant that, overall, around 80% of the EEA rural area was identified to be non-mountainous.

[45] Fresnel zone is a series of concentric prolate ellipsoidal regions of space between and around a transmitting antenna and a receiving antenna system.

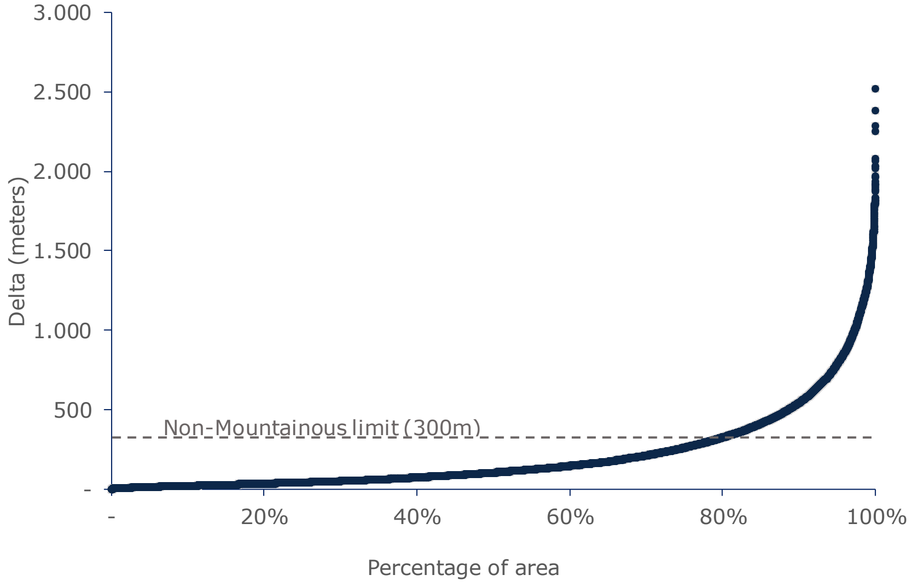


Figure 3.9: Geographical inputs – Topography of the terrain – Delta vs percentage of area [Source: Axon Consulting]

3.2.4.2. Results

Having assessed the topography of the rural samples across EU/EEA countries, and considering a 300m threshold to classify a sample as mountainous, the exhibit below displays the percentage of the rural area classified as mountainous and non-mountainous in EU/EEA countries.

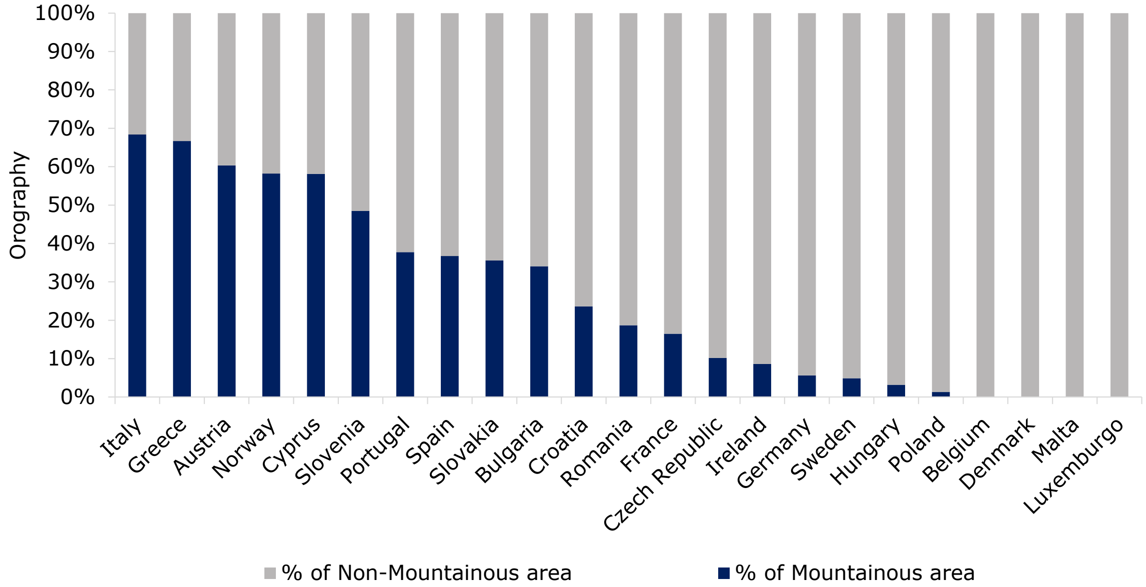


Figure 3.10: Geographical inputs – Topography of the terrain –Percentage of Mountainous/non-mountainous area per country [Source: Axon Consulting]

As shown above, Italy is the most mountainous EU/EEA country in rural areas, while a number of countries including Belgium, Denmark, Malta or Luxemburg are not assumed as mountainous at all.

3.3. Other inputs

In addition to all the inputs defined in the previous sections, the model uses a set of other inputs that are described in this section. They mostly correspond to inputs that are either standard across the industry, come directly from renowned references or that have a reduced materiality on the results.

The table below summarises these cases:

Model input	Sources of information	Comments
Cost adjustment factors (Worksheet: 1G INP COST ADJ FACTORS)	Public sources (World Bank[46], Eurostat[47])	These inputs include information corresponding to exchange rates and the purchasing power parity (ppp) index. These factors are employed in the model to normalise OpEx-related figures across EEA countries.
Erlang tables (Worksheet: 2I INP ERLANG)	Public source	Erlang tables are a set of statistical tables used to dimension networks which are available in the public domain. For instance, the reference http://www.pitt.edu/~dtipper/2110/erlang-table.pdf includes the Erlang B and Erlang C tables.
Access network dimensioning parameters (Worksheet: 2A INP NW)	Standards, public references and average industry references	These values refer to intrinsic characteristics of mobile access networks including spectrum bandwidth, blocking probability, bitrate, etc. In order of priority, these were extracted from network standards, public references or average industry values from Axon's database.
Backhaul network dimensioning parameters (Worksheet: 2A INP NW)	Standards, public references and average industry references	These values refer to intrinsic characteristics of mobile access networks including number of sites per hub, sectors per site, hexagon area factor, etc. In order of priority, these were extracted from network standards, public references or average industry values from Axon's database.

[46] PPP exchange rates from World bank – https://data.worldbank.org/indicator/PA.NUS.PPP?end=2022&start=2022&view=bar&year_high_desc=true

[47] Euro/ECU exchange rates - annual data: http://ec.europa.eu/eurostat/web/products-datasets/-/ert_bil_eur_a

Model input	Sources of information	Comments
Constant parameters (Worksheet: 2A INP NW)	Public sources and standards	Intrinsic constants that need to be considered in the model. For instance, number of bits in a byte, seconds in an hour, etc.
Other network parameters (Worksheet: 2A INP NW)	Public references and average industry references	Different parameters related to network dimensioning. For instance, overheads generated by idle traffic, spectral efficiency or maximum network load.
Core equipment capacity (Worksheet: 2A INP NW)	Stakeholders	Core equipment capacity is defined by taking the average of the references received while excluding the upper and lower 20% of the values, following the same methodology as described for the calculation of the unit costs of the assets. As equipment was reported in different capacity units, there were cases when more than one capacity was introduced in the model for the same equipment.
Cell Radii (Worksheet: 2C INP CELL RADIUS)	Stakeholders (based on information received in SMART 2017/0091)	Cell radii are defined in the model per technology, spectrum band and geotype. Considering that cell radii inputs should not vary over the years, these inputs have been maintained from the previous SMART 2017/0091.

Model input	Sources of information	Comments
Backbone (Worksheet: 2F INP BACKBONE & CORE)	Stakeholders (based on information received in SMART 2017/0091)	Detailed inputs that characterise the backbone network of the reference operator in each EEA country were produced during SMART 2017/0091. In the current assignment CNECT/2022/OP/0065, it has been observed that the information reported by operators in the Data Request Form about their backbone networks (e.g. number of core nodes, core node locations, etc.) was considerably less complete than in the previous cost study SMART 2017/0091 for the vast majority of countries. Taking this situation into account, as well as the fact that the layout of the backbone networks is not expected to have undergone substantial changes[48] since 2017, we have opted for keeping the backbone inputs from the previous SMART 2017/0091.

Figure 3.11: Other inputs – Summary [Source: Axon Consulting]

[48] Please note that we refer to the location of the backbone network nodes, as capacities required - which evidently may have increased as a result of the increase in mobile traffic observed over the last years – are directly calculated by the model based on the traffic requirements of the modelled reference operator (i.e., such capacities do not represent a model's input).

4. New elements added in the model's update

As already anticipated in Workshop 1, in order to reflect the latest technological innovations and trends that have taken place during the recent years in the mobile markets, the following two main elements have been incorporated during the model's update:

- Incorporation of 5G
- Separation of M2M services

4.1. Incorporation of 5G

This section describes the changes introduced within the model regarding the incorporation of 5G networks. These changes can be grouped into the following three items, which are described in the following sub-sections:

- Inclusion of new spectrum bands
- Implementation of the 5G network design
- Consideration about small cells

Inclusion of new spectrum bands

The integration of the 5G into the model entails the allocation of spectral bands which can be employed by this technology. To achieve this, as already outlined in section 3.1.5, the model incorporates the new bands which have been recently and mostly auctioned by countries for 5G networks (namely, 3400-3800 MHz and 26 GHz), in addition to the list of shared spectrum bands with other access technologies (2G, 3G and 4G), already used and available in the previous version of the model from SMART 2017/0091. Finally, it must also be outlined that the 2600–TDD spectrum band has also been newly added during the model's update for both 4G and 5G technologies, due to the proliferation that the utilization of this band has shown in the past years.

In summary, the following illustration shows the spectral bands that may be employed by the 5G, and whose assignation is performed in worksheet '1E INP SPECTRUM' of the model for each country:

Technology	Spectrum
5G	SPEC.700MHz
5G	SPEC.800MHz
5G	SPEC.900MHz
5G	SPEC.1800MHz
5G	SPEC.2100MHz
5G	SPEC.2600MHz
5G	SPEC.2600MHz (TDD)
5G	SPEC.3.400-3.800 MHz (TDD)
5G	SPEC.26000MHz (TDD)

Figure 4.1: Spectral bands that may be employed by the 5G [Source: Axon Consulting]

Implementation of the 5G network design

The design algorithms for **5G access networks** have been incorporated in block 6 of the model, and more particularly, in worksheet '6D CALC DIM 5G'. This worksheet is dedicated to calculating the equipment (number of network elements/resources) required to handle the 5G traffic in the network, for each increment and each geotype:

Contents

Sheet	Name
6A CALC DIM GSM	GSM Network Dimensioning by Geotype
6B CALC DIM UMTS	UMTS Network Dimensioning by Geotype
6C CALC DIM LTE	LTE Network Dimensioning by Geotype
6D CALC DIM 5G	5G Network Dimensioning by Geotype
6E CALC DIM SITES	Sites Dimensioning by Geotype
6F CALC DIM BACKHAUL	Backhaul Dimensioning by Geotype
6G CALC DIM CORE	Core platforms Dimensioning
6H CALC RES GEO	Resources Consolidation

Figure 4.2: Block 6 worksheets structure – 5G dimensioning [Source: Axon Consulting]

In terms of network design, as already anticipated in Workshop 1, the incorporation of the 5G technology into the model has adopted a continuity approach, by implementing a set of technical algorithms equivalent to those already existing for 4G networks in the previous model, but recognizing the main differences existing between both types of networks, mainly: i) usage of spectrum bands ii) spectral efficiencies (bps/Hz) and iii) deployment of small-cells for 5G (see next sub-section). These algorithms are fed from the inputs previously introduced in blocks 1 and 2 of the model, in a manner consistent with the inputs previously established for 2G, 3G and 4G networks[49].

In addition to the inclusion of the new worksheet '6D CALC DIM 5G' for the design of the 5G access network equipment, during the model's update, it has also been necessary to accordingly adapt the design of access sites, backhaul and core elements to take into consideration the effect of the 5G traffic. To achieve this, worksheets '6E CALC DIM SITES', '6F CALC DIM BACKHAUL', and '6G CALC DIM CORE' have been respectively adjusted.

Finally, regarding the design of the **core equipment for 5G networks**, the model introduces a dimensioning on a per-user basis (i.e., the number of units for the network resource is assumed equivalent to the number of users). The utilization of this approach, instead of a design of the core network based on differentiated core platforms/solutions has been the preferred method due to the lack of sufficiently detailed data about 5G core platforms received from countries during the data collection phase. This approach is also aligned with common practices most recently observed in the market regarding the commercialization of 5G core equipment by manufacturers, which generally do not differentiate individual costs per platform/function, and instead, they charge operators a global investment for all 5G core related elements. This implementation is included in worksheet '6G CALC DIM CORE' of the model.

Consideration about small cells

Given that the deployment of 5G networks may be accompanied by the roll-out of small-cell sites to provide enhanced capacity, the updated model already includes the possibility of dimensioning such small-cell sites.

The technical algorithm has been implemented in worksheet '6D CALC DIM 5G', in conjunction with the overall design of 5G access networks described in the previous sub-section. As described in the Descriptive Manual of the model, this algorithm takes as starting point an input that corresponds to the "Percentage of 5G traffic handled by small-cell sites over the total 5G traffic", located in worksheet '2A INP NW' of the model:

[49] As an example, for the case of the coverage input, while the model previously presented coverage information for 2G, 3G and 4G networks, as part of the model's update, the coverage input has been extended to include 5G coverage. The detail of how the model's inputs have been determined is included in section 3 of this same document.

Percentage of 5G traffic handled by small-cell sites over the total 5G traffic

Country	Parameter	Units	2022	2023	2024	2025
Austria	5G traffic over small-cell sites	%	-	-	-	-
Belgium	5G traffic over small-cell sites	%	-	-	-	-
Bulgaria	5G traffic over small-cell sites	%	-	-	-	-
Croatia	5G traffic over small-cell sites	%	-	-	-	-
Cyprus	5G traffic over small-cell sites	%	-	-	-	-
Czech Republic	5G traffic over small-cell sites	%	-	-	-	-
Denmark	5G traffic over small-cell sites	%	-	-	-	-
Estonia	5G traffic over small-cell sites	%	-	-	-	-
Finland	5G traffic over small-cell sites	%	-	-	-	-
France	5G traffic over small-cell sites	%	-	-	-	-
Germany	5G traffic over small-cell sites	%	-	-	-	-

Figure 4.3: Small cells dimensioning parameter [Source: Axon Consulting]

In this manner, based on the traffic that operators foresee to handle through these types of small-cell sites, the model estimates the number of required small-cell sites by dividing such traffic by the average capacity per small-cell.

Nevertheless, although the above feature has been incorporated into the model, it is necessary to emphasize that, based on the information received in the data collection process from the EU/EEA countries, the traffic over small-cell sites informed by NRAs has been zero in many cases, and a very reduced figure (5% or lower) in a few others[50]. For this reason, we have considered it prudent, especially given the negligible expected utilization of these solutions based on the received information, to "deactivate" the utilization of small-cell sites for all countries. Hence, for a matter of consistency, the input shown in the previous table presents a value of zero in all EU/EEA countries.

Nevertheless, if based on future model's updates (see section 6 for further details on them), different patterns were observed in the EU/EEA countries regarding the utilization of small-cell sites, the utilization of these solutions in the model would be reconsidered at that time.

4.2. Separation of M2M services

As also presented in Workshop 1, given the proliferation of M2M services during last years, the EC/Axon have considered it appropriate to include a functionality in the model to recognize that patterns of M2M services may be different from those of traditional services provided to end-customers, hence leading to differentiated costs for both types of services.

[50] No country has informed a figure higher than 5% for the requested time period.

This assessment has been performed from two different perspectives, which are described in the following sub-sections:

- Signalling Management
- Traffic Management

Signalling Management

It consists in the use of signals for controlling communications and constitutes an information exchange concerning the establishment and control of a telecommunication channel.

During Workshop 1, the Axon/EC presented that, based on their views, this component should have a negligible impact in costs for operators, and as such, proposed not to consider it within the model. However, considering that some stakeholders showed their disagreement with such proposal (despite no evidence was provided as part of their responses), the Axon/EC still considered it convenient to collect data to evaluate the potential impact of the signalling component.

After having assessed the received data, the following conclusions can be obtained:

- *Access networks*. Operators showing their disagreement with Axon/EC's proposal generally stated that an access site commonly has a technical constraint concerning the number of connections that may be simultaneously established. Even if this constraint is not expected to create an impact on 4G and 5G networks, which have been designed to deal with large connection densities, operators argued this was not still the case for legacy technologies such as 2G and 3G, for which a considerable increase in the number of M2M connections could be expected (as many M2M solutions still work on those legacy technologies). However, after assessing the forecasts regarding the number of M2M connections provided by EU/EEA countries, even if such forecasts diver significantly among them, we observed that the majority of them are actually informing a decrease in the expected number of M2M connections for both 2G and 3G technologies towards the future, with only very few exceptions of countries reporting increases of M2M connections for these technologies (in particular, only three countries reported increases for 2G connections and only one country reported an increase for 3G connections), but with values of reported increases which cannot be considered in any case as massive. Thus, coupling the previous points with the fact that a considerable number of countries have informed a phase out of 2G or 3G networks in the next years, it can be concluded that the number of M2M connections for 2G and 3G is not expected to exert an impact on the operators' costs of EU/EEA countries.

Additionally, in the case of 4G and 5G networks, considering that these are expected to be the dominant technologies in the future, we have calculated the average number of simultaneous connections per site, for the modelled time period and based on the model's outcomes, and compared it with the average *"Maximum number of users/devices that can be connected simultaneously to the site"* informed by operators in the data collection process[51]. This assessment has shown that the estimated figure of connections per site in each EU/EEA country does not exceed the maximum capacity per site, hence indicating that based on the available information, the number of connections is not expected to (at least considerably) influence the number of sites needed in the modelled 4G and 5G networks (i.e. not implying an additional cost for operators).

- *Core networks*. Operators showing their disagreement with Axon/EC's proposal stated that the number of connections/users is the relevant parameter in the design of certain core equipment. To this respect, it should be mentioned that the design of core platforms in the model already takes into account the number of connections when such parameter may entail a relevant constraint in the dimensioning. This is particularly the case of the following core elements used by wholesale mobile services: SGSN, GGSN, MME, PCRF, CSCF and 5G Core[52]. Nevertheless, we observe that the share of the costs related to these core platforms over the total costs needed in the network barely represents the 2% (EU/EEA average).

In light of the above findings, the EC/Axon can conclude, in alignment with their proposal presented in Workshop 1, that only the traffic-related component is expected to play a relevant role in investments required for the provision of M2M services.

Traffic Management

It consists in the transmission of data, voice or messages, carried over a telecommunication channel in a given period.

[51] For the basic access site configurations requested in the data collection, the average of reporting EU/EEA countries is 5312 connections/site and 3192 connections/site, for 4G and 5G respectively.

[52] It is also worth outlining that operators have not informed any additional specific equipment cost needed in the provision of services making use of the technologies NB-IoT (Narrowband Internet of things) and LTE-M (LTE Machine Type Communication), requested in item 'NB-IoT and LTE-M SPECIFIC COSTS' of worksheet 'EQUIPMENT UNIT COSTS' in the Data Request. Actually, only one operator had informed a negligible investment for a presumably 'C-IoT license', but for which additional details such as operating capacity were missing.

Taking into account that traffic consumption patterns of M2M services may have different profiles than those of traditional mobile broadband services provided to end-customers, the update model introduces a functionality allowing to differentiate costs for both types of services. Based on the analysis of the received information during the data collection process, we identified that the different usage patterns are mostly linked the technological use of the access networks (2G, 3G, 4G and 5G), as M2M services still tend to rely more on 2G and 3G than the traditional services provided to end-customers.

As a result of this, the unit costs for these two types of services have been differentiated by making use of the following formulas:

M2M services

$$
\begin{aligned}
&Cost\ of\ data\ services\ for\ M2M\ \left(\frac{EUR}{GB}\right)\\
&\quad = Cost\ of\ data\ in\ 2G\ networks\ \left(\frac{EUR}{GB}\right) x\ \%\ of\ M2M\ traffic\ handled\ by\ 2G\ networks\\
&\quad + Cost\ of\ data\ in\ 3G\ networks\ \left(\frac{EUR}{GB}\right) x\ \%\ of\ M2M\ traffic\ handled\ by\ 3G\ networks\\
&\quad + Cost\ of\ data\ in\ 4G\ networks\ \left(\frac{EUR}{GB}\right) x\ \%\ of\ M2M\ traffic\ handled\ by\ 4G\ networks\\
&\quad + Cost\ of\ data\ in\ 5G\ networks\ \left(\frac{EUR}{GB}\right) x\ \%\ of\ M2M\ traffic\ handled\ by\ 5G\ networks
\end{aligned}
$$

Traditional services to end-customers

$$
\begin{aligned}
&Cost\ of\ data\ services\ for\ traditional\ services\ \left(\frac{EUR}{GB}\right)\\
&= Cost\ of\ data\ in\ 2G\ networks\ \left(\frac{EUR}{GB}\right) x\ \%\ of\ traditional\ traffic\ handled\ by\ 2G\ networks\\
&+ Cost\ of\ data\ in\ 3G\ networks\ \left(\frac{EUR}{GB}\right) x\ \%\ of\ traditional\ traffic\ handled\ by\ 3G\ networks\\
&+ Cost\ of\ data\ in\ 4G\ networks\ \left(\frac{EUR}{GB}\right) x\ \%\ of\ traditional\ traffic\ handled\ by\ 4G\ networks\\
&+ Cost\ of\ data\ in\ 5G\ networks\ \left(\frac{EUR}{GB}\right) x\ \%\ of\ traditional\ traffic\ handled\ by\ 5G\ networks
\end{aligned}
$$

The above implementation has been introduced in worksheet '9B OUT SERV LRIC UNIT COST' of the model, in the module named as *"Support calculations to separate results of data services between i) traditional data services provided to end-customers and ii) M2M / IoT data services"*.

For the estimation of the percentages of traffic per technology used by the two types of services, the following procedure has been followed:

- *M2M services*. In the first place, it should be recognized that the information received for differentiating traffic between M2M services and traditional services (requested in section 'TRAFFIC DISTRIBUTION PER TECHNOLOGY' of the Data Request) presented the following limitations:
  - Only a limited number of countries provided the needed information for establishing such differentiation between M2M and traditional services.
  - Among the reporting countries, only three countries have submitted forecasts of M2M services for next years (2024 onwards).
  - Information received still presented a considerable number of inconsistencies[53].

  In light of the above, a common approach has been established for all countries, by relying on EU/EEA average ratios. More specifically, for each access technology (2G, 3G, 4G and 5G) and country, we have calculated the following ratio based on the available information:

$$Ratio\ for\ 2G = \frac{Percentage\ of\ 2G\ traffic\ considering\ only\ M2M\ services\ ^{54}}{Percentage\ of\ 2G\ traffic\ considering\ all\ services\ (M2M\ and\ traditional\ services)^{55}}$$

  The same approach has been followed for 3G, 4G and 5G technologies. Calculated figures have demonstrated that the M2M services rely more on 2G and 3G services (leading to ratios higher than 1 for these technologies) and less on 4G and 5G services (leading to ratios lower than 1 for these technologies) when compared to traditional services.

  Based on the obtained figures per country, an EU/EEA average ratio has been computed for each access technology.

  Then, the obtained ratios for M2M services have been applied to the traffic distribution per technology over the years, previously calculated as described in section 3.1.8., which already takes into account the combined traffic of M2M services and traditional services[56]. Finally, the calculated percentages have been adjusted to ensure they add

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[53] The two most common cases were: i) Unreasonable evolutions and ii) Percentages received for the 'DATA' category (with the combination of traffic for M2M and traditional services) did not fall between the range established by two values from the sub-categories 'DATA - Traditional data services provided to end-customers' and 'DATA - M2M/IoT data services'. This is presumably due to the fact that a different number of operators may have reported the requested figures per country (e.g. if three operators have reported the 'DATA' category, but only two operators report the sub-categories 'DATA - Traditional data services provided to end-customers' and 'DATA - M2M/IoT data services', the averages of their reported values, when calculated by the NRAs, may lead to the observed inconsistencies).

[54] Category 'DATA - M2M/IoT data services' of the Data Request.

[55] Category 'DATA' of the Data Request.

[56] These percentage inputs are included in worksheet '1I INP TECHNOLOGY DIS' of the model, under the category 'Data'.

up to 100% every year. The percentage inputs obtained for M2M services are included in worksheet '1I INP TECHNOLOGY DIS' of the model, under the category 'Data - M2M'.

- *Traditional services to end-customers*. Percentages for this type of services are derived from the percentages for the total data traffic (described in section 3.1.8) and those of the M2M services (described in the previous point). For this purpose, the following formula is applied for each access technology (the example is focused on the 2G technology but the same applies to all others) and country:

$$\textit{Percentage of 2G traffic considering only traditional services} = \frac{\textit{Percentage of 2G traffic considering all services (M2M and traditional services))} - \textit{Percentage of 2G traffic considering only M2M services x Share of M2M services traffic over the total}}{\textit{Share of traditional services traffic over the total}}$$

Where the shares of M2M services and traditional services traffic have been obtained from the ITU's forecasts[57] for these two types of traffic, for the upcoming period until the year 2032:

% of traffic	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Traditional services to end-users	91,1%	90,8%	90,5%	89,5%	88,5%	87,5%	87,1%	86,6%	86,2%	85,8%	85,3%
M2M services	8,9%	9,2%	9,5%	10,5%	11,5%	12,5%	12,9%	13,4%	13,8%	14,2%	14,7%

Table 4.1: % of traffic for Traditional services to end-users and M2M services [Source: ITU]

It should be mentioned, that in the case of the percentages for traditional services to end-users, these are directly calculated in the model, based on the above inputs, also in worksheet '9B OUT SERV LRIC UNIT COST'.

4.2.1. Cost-recovery scenarios for M2M services

During the first consultation on the model, some stakeholders have expressed that the cost of M2M data services should not be exclusively recovered by means of a cost per unit of traffic (EUR/GB), but also considering an additional cost per customer (EUR/Customer/Day). According to them, this is particularly relevant in the case of M2M services, as the traffic generated by M2M applications may be very reduced in certain cases.

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[57] This input is introduced at the end of worksheet '1I INP TECHNOLOGY DIS' of the model.

Taking into account the received feedback, we have introduced, at the request of the EC, a new possibility within the model for cost-recovery for M2M services, allowing to have results under two different approaches:

- *Option 1*. The cost of M2M data services is exclusively recovered by means of a cost per unit of traffic (EUR/GB). This corresponds to the cost-recovery approach available in the model submitted to the first consultation.
- *Option 2*. The cost of M2M data services is recovered by a mix of a cost per unit of traffic (EUR/GB) and a cost per customer on a daily basis (EUR/Customer/Day). This is the new cost-recovery approach, which has been added in the model submitted to the second consultation.

More specifically, Option 2 relies on the idea that the share of common costs of data services, presenting a more fixed nature, should be allocated to data services (traditional and M2M) taking into account the number of customers instead of the volumes of traffic (volumes of GB). On the other hand, incremental costs of data services, being significantly dependent on the traffic levels would still keep an allocation based on the volumes of traffic. With this idea in mind, the cost-allocation for data services would rely on the following criteria:

Cost type	Option 1	Option 2
Incremental costs	All costs of data services are allocated between Traditional and M2M services taking into account the split of traffic volumes (GB) handled by Traditional and M2M services, respectively.	Incremental costs of data services are allocated between Traditional and M2M services taking into account the split of traffic volumes (GB) handled by Traditional and M2M services, respectively. In the case of M2M services, incremental costs finally allocated will determine the cost per unit of traffic (EUR/GB).
Common costs[58]		Common costs of data services are allocated between Traditional and M2M services taking into account the split of customers of Traditional and M2M services, respectively. In the case of M2M services, common costs finally allocated will determine the cost per customer (EUR/Customer/Day).

Table 4.2: Criteria for cost-allocation under Option 1 and Option 2 [Source: Axon Consulting]

It is important to also outline the following aspects:

- In the case of data traditional services provided to end-customers, the adopted cost-recovery scheme is always a cost per unit of traffic (EUR/GB), regardless of the scenario that is selected for M2M services (Option 1 or 2). However, the selection of Option 1 or 2 has an impact not only on M2M services, but also on traditional services, given that commons costs are allocated among them using different criteria (i.e., traffic under Option 1 and customers under Option 2).
- In the case of data M2M services, the total cost of the service is constituted by the sum of the two components: i) the cost per unit of traffic (EUR/GB) and ii) the cost per customer on a daily basis (EUR/Customer/Day). However, if the Option 1 is selected, the model will logically produce a cost per customer equal to zero.

In order to implement the new Option 2, the following inputs have been added into the model submitted to the second consultation:

[58] Including G&A costs.

- The share of M2M and traditional customers has been incorporated in worksheet "1I INP TECHNOLOGY DIS". This share has been determined for the year 2022 based on an EEA average and subsequently extrapolated towards future years assuming a constant ratio between the number of customers and of traffic for M2M services, leading to the following figures:

% of customers	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Traditional services to end-users	82,5%	81,8%	81,3%	79,2%	77,3%	75,3%	74,4%	73,6%	72,7%	71,9%	71,0%
M2M services	17,5%	18,2%	18,7%	20,8%	22,7%	24,7%	25,6%	26,4%	27,3%	28,1%	29,0%

Table 4.3: % of customers for Traditional services to end-users and M2M services [Source: Axon Consulting based on EEA average]

It should be explained that this approach, based on an EEA average is the preferred method due to the following reasons: i) Only few countries had reported information regarding the split of customers between traditional and M2M services in the long-term, and in most of these cases, reported figures were hardly reliable or robust, as they were high-level estimations ii) To guarantee an adequate cost-recovery pattern, it is essential to keep consistency between the split of traffic and the split of customers assumed in the model for M2M and traditional services. Hence, considering that, as explained in previous paragraphs of this section 4.2, we had relied on EEA averages for the split of traffic (due also to the limitations in the information received for such traffic patterns), it is therefore essential to respect an equivalent approach when defining the split of customers for M2M and traditional services, or otherwise, we could introduce significant misalignments within the model.

- The number of roamer days (number of days spent by roamers in the country during the year) has also been incorporated in worksheet "1I INP TECHNOLOGY DIS". This input had already been informed by countries during the data collection process. Additionally, in the case of forecasts for such roamer days, these were also previously available thanks to the "Step 1: Roamer days forecast" described in section 3.1.2.3 of this same document. In this manner, when the Option 2 is selected, in the model's calculations, the number of roamer days (for international customers) is combined with the demand of subscribers (for national customers) to determine the cost that a unique customer should recover in a single day, leading to the corresponding cost per customer on a daily basis (EUR/Customer/Day).

The new implementation regarding the allocation of common costs under Option 2 has been introduced in worksheet '9B OUT SERV LRIC UNIT COST' of the model, in the module named as *"Support calculations to perform the allocation of common costs based on customers (instead of on traffic)"*.

Finally, we explain that, as already described in section 2.6, in order to assess the impact in results of the two available options, the model submitted to the second consultation incorporates the following two scenarios, which can be selected from the COVER worksheet:

- *Common costs allocated based on traffic*. Results under this scenario correspond to the Option 1 which has been described in this section.
- *Common costs allocated based on customers*. Results under this scenario correspond to the Option 2 which has been described in this section.

5. Main outcomes of the cost model

This section provides an overview of the main outcomes produced by the model, both under the network allocation module and the regulatory policy allocation module. The results obtained under the former are presented in worksheet '9G OUT RESULTS – NW' while the outcomes obtained under the latter are included in worksheet '10C OUT RESULTS – POLICY'. Finally, worksheet '10E OUT IMPACT CHART' includes a pivot chart to help stakeholders assess the cost differences observed under both scenarios.

Further indications on the methodological differences between the two cost allocations modules are presented in the Annex 3 – Descriptive manual.

The data fields presented in worksheets '9G OUT RESULTS – NW' and '10C OUT RESULTS – POLICY' are fully equivalent, differing only in terms of the results produced.

Additionally, stakeholders should note that the EC/Axon team has performed a reconciliation assessment to ensure the representativeness of the results in the EU/EEA region. The reconciliation assessment performed is described in sections 5.1 and 5.2 below and has resulted in the verification that the model's results are aligned with the realities faced by MNOs in each country. This means that when the results of the model (in terms of number of network elements and cost base) are aligned with those of an average MNO with similar characteristics to the modelled reference operator, the results are considered to be within a reasonable range of confidence. On the contrary, those parameters and scenarios that produce results that present significant differences with MNO's realities should be considered as mis-reconciled and cannot be taken as a reference.

The sections below seek stakeholders' feedback on the following elements of the model:

- Network sites
- Cost Base
- Roaming data costs per year and country (EUR/GB)
- Voice termination costs per year and country (EURcents/min)
- Voice roaming costs per year and country (EURcents/min)

5.1. Network sites

The table "Overview of the number of sites modelled" in worksheets '9G OUT RESULTS – NW' and '10C OUT RESULTS – POLICY' illustrates the number of access sites per country and year obtained for the reference operator. The number of access sites illustrated in this table is actually calculated in worksheet '6D CALC DIM SITES' of the model.

In this context, it is worth noting that in recent years there has been a massive proliferation of site sharing scenarios between mobile operators (both active and passive schemes) as well as the leasing of sites from TowerCo companies, which makes it basically infeasible to perform any kind of reconciliation exercise between the number of sites estimated by the model and the number of sites reported in the data collection process by each country[59]. For this reason, in this study, we have focused the reconciliation exercise of the model on the cost base, as detailed in the following section.

5.2. Cost Base

5.2.1. Reconciliation assessment

Bottom-up cost models are techno-economical tools that heavily rely on the inputs employed. Contrary to Top-down models, Bottom-up models are not based on the financial statements of operators and, thus, their results may differ from those resulting from MNOs' real operations.

Therefore, it is crucial to understand what these differences are, and to make sure these fall within a narrow range, to prove the reliability of the results they produce. The process of verifying the alignment of the model's results with the MNOs' realities is referred to as the reconciliation process.

The assessment of the reconciliation of the cost base produced by the model to the MNOs' realities was performed following the steps described below:

- **Definition of a reasonable benchmark for comparison**. This step comprised the definition of the relevant references for comparison for both OpEx and depreciation for the year 2022. The sub-steps adopted to define each of them are described below:
  - Depreciation
    a) The costs presented under the "Depreciation and amortization – Network" row of the P&L were converted to EUR.

[59] In addition to that, for many countries, the lack of sufficiently detailed information received during the data collection process prevents the identification of what would be the average number of sites for a reference operator in such country.

b) If not available, these were extracted as the sum of the mobile network annual depreciation from the FAR (also converted to EUR). The "Others" category within the FAR was only considered when it included thorough descriptions that made it clear that it actually included network-related costs.

c) In case of references related with MNOs with very small market shares (i.e. less than 5%) or which felt significantly above/below the references provided by other operators in the same country, these were discarded.

d) Based on the outcomes of the steps described above, two references were extracted, namely i) the average of all reporting (and accepted) MNOs and ii) the sum of reporting MNOs' depreciation, divided by the sum of their market share, multiplied by the reference operator's market share (i.e. depreciation adjusted to reference operator's scale).

- OpEx

a) The costs presented under the following rows of the P&L were fully considered, as they are network-related, and converted to EUR:

  - Radio spectrum and operating license fees
  - Telecom facility operating lease rentals
  - Telecom facility utilities
  - Network outsourced maintenance

b) Staff costs were only considered to the extent these were related to the operation of the mobile network. As such, only the percentage of staff costs related to the "Network – Mobile" category from the "STAFF" worksheet of the data request were considered. These costs were also converted to EUR.

c) Put in another way, the P&L categories that were not included in the calculation of the network OpEx were

  - Cost of goods sold
  - Interconnection and roaming
  - General and administration expenses[60]
  - Marketing and sales expenses

[60] It should be noted that the assessment of the reconciliation of the cost base was performed net of G&A expenses.

- Other expenses
- Depreciation and amortization – Network
- Depreciation and amortization - Non-network

d) In case of references related with MNOs with very small market shares (i.e. less than 5%) or which felt significantly above/below the references provided by other operators in the same country, these were discarded.

e) Based on the outcomes of the steps described above, two references were extracted, namely i) the average of all reporting (and accepted) MNOs and ii) the sum of reporting MNOs' OpEx, divided by the sum of their market share, multiplied by the reference operator's market share (i.e. OpEx adjusted to reference operator's scale).

- **Identification of the cost base (OpEx + depreciation) produced by the model**:
  - OpEx. Worksheet '9F OUT RES COSTS' includes the detailed cost components that were calculated by the model for a given country, separated between OpEx and CapEx, per year. This worksheet was employed to extract the reference OpEx[61] for the year 2022.
  - Depreciation. In order to provide a valid comparison, the depreciation profile calculated by the model should mimic that of a linear depreciation, typically used in the financial statements of the operators. Therefore, in order to extract the proper cost base used for reconciliation purposes, the Gross Book Value (GBV) per network resource available in worksheet '7B CALC CAPEX' of the model was divided by the corresponding useful lives, to extract the reference depreciation for the year 2022:
- **Assessment of the differences between the two references**: The reference produced by the model described in the second step was finally compared with the closest of the two references (OpEx + depreciation) defined in step one to assess the existing differences. The cost of capital calculated by the model is not considered in this comparison. This exercise showed that the differences registered were always below ±20%.

[61] Without G&A expenses.

5.2.2. Cost base calculated by the model

The table "Overview of the total cost base (EUR)" in worksheets '9G OUT RESULTS – NW' and '10C OUT RESULTS – POLICY' illustrates the total annualised costs (OpEx, depreciation and cost of capital) calculated per year for the reference operator in each country, depending on the annualisation criteria selected in the control panel of the model. It includes network, G&A and wholesale specific costs. It should be noted that in the reconciliation exercise cost of capital and G&A costs were not be considered.

This information is presented in EUR for all the countries and is obtained from worksheet '9A OUT SERV LRIC TOT COST' of the model.

5.3. Roaming data costs per year and country (EUR/GB)

The tables "Roaming data costs per year and country (EUR/GB) for traditional services provided to end-customers" and "Roaming data costs per year and country for M2M services (table 10.A for the cost per unit of traffic – measured in EUR/GB – and table 10.B for the cost per user on a daily basis - measured in EURcents / Customer (SIM Card) / Day-)[62]" in worksheets '9G OUT RESULTS – NW' and '10C OUT RESULTS – POLICY' illustrate the roaming-in (within the EU/EEA) data costs per year, differentiating results between traditional services provided to end-customers and M2M services.

The costs presented in the model include national network costs only and, therefore, do not include the transit costs that are later discussed in section 7.

This information is extracted from worksheet '9B OUT SERV LRIC UNIT COST' in the network allocation module and from worksheet '10B CALC EC REG. POLICY ALLOC' in the regulatory policy module.

5.4. Voice termination costs per year and country (EURcents/min)

The table "Voice termination costs per year and country (EURcents/min)" in worksheets '9G OUT RESULTS – NW' and '10C OUT RESULTS – POLICY' illustrates the voice termination costs per year in EURcents/min.

[62] The two components 10.A and 10.B must be added together to make up the total cost of the service.

This information is extracted from worksheet '9B OUT SERV LRIC UNIT COST' in the network allocation module and from worksheet '10B CALC EC REG. POLICY ALLOC' in the regulatory policy module.

5.5. Voice roaming costs per year and country (EURcents/min)

The table "Voice roaming costs per year and country (EURcents/min)" in worksheets '9G OUT RESULTS – NW' and '10C OUT RESULTS – POLICY' illustrates the roaming-in (within the EU/EEA) voice costs per year in EURcents/min. The costs presented in the model include national network costs only and, therefore, do not include the transit costs that are later discussed in section 7, neither termination costs.

This information is extracted from worksheet '9B OUT SERV LRIC UNIT COST' in the network allocation module and from worksheet '10B CALC EC REG. POLICY ALLOC' in the regulatory policy module.

6. Process for future model's updates

As announced in Workshop 1, beyond the main update of the model which has been conducted in 2023, the EC also plans to carry out additional input updates in the subsequent years (until 2027), with the main objective of having updated results that reflect the latest trends in mobile services of EU/EEA countries.

These updates will be focused on the inputs that are more subject to YoY modifications and that may exert a more relevant impact on the model's results. This approach is designed to reduce the burden that a complete update would impose on all stakeholders, including operators, NRAs, EC, Axon, etc.

Regarding the frequency of the input updates, even if yearly updates were originally planned by the EC/Axon, after assessing the feedback received to Workshop 1, the EC/Axon concluded that they might finally perform these updates every two years, in order to minimize the burden imposed on operators and NRAs. The exact dates for the next data collection process will be communicated by the EC to the NRAs in due course.

For the purpose of these input updates, a separate and simplified data request will be prepared. It should be mentioned that the data requested will cover the historical period (starting from the year when the previous data collection was carried out) as well as updated forecasts for the upcoming years (until the year 2032). Particularly, the following items will be requested:

- Demand for the following services[63]:
  - Total SIM Card Subscribers
    - Traditional end-customers
    - M2M lines
  - Roaming inbound users (including from EU/EEA and non-EU/EEA)
  - Domestic Data Traffic
  - Roaming inbound Data Traffic (including EU/EEA and non-EU/EEA)

[63] In the case of the demand, with the intention of also reducing the burden on operators, demand requested about services will be aggregated. For instance, Domestic Voice traffic will be requested in an aggregated manner (in a unique row within the Excel), jointly including the traffic of On-net, Off-net national, Off-net international, Incoming from national and Incoming from international.

- Domestic Voice (including On-net, Off-net national, Off-net international, Incoming from national and Incoming from international)
- Roaming inbound Voice (including Outgoing-EU/EEA, Incoming-EU/EEA, Outgoing -Non EU/EEA and Incoming-Non EU/EEA)
- Domestic SMS (including On-net, Off-net national, Off-net international, Incoming from national and Incoming from international)
- Roaming inbound SMS (including Outgoing-EU/EEA, Incoming-EU/EEA, Outgoing - Non EU/EEA and Incoming-Non EU/EEA)

- Coverage, population coverage disaggregated per technology:
  - 2G population coverage
  - 3G population coverage
  - 4G population coverage
  - 5G population coverage
- Spectrum
  - Bandwidth (MHz) disaggregated per access technologies (2G, 3G, 4G and 5G), for each spectrum band:
    - 700MHz
    - 800MHz
    - 900MHz
    - 1800MHz
    - 2100MHz
    - 2600MHz
    - 2600MHz (TDD)
    - 3400-3800 MHz (TDD)
    - 26GHz (TDD)
  - Spectrum costs related to new auctions that may have taken place in the country since the previous data collection process.
- Split of traffic per technology, disaggregated per access technologies (2G, 3G, 4G and 5G), for the following types of services:
  - Data
    - Data - Traditional data services provided to end-customers

- DATA - M2M/IoT data services
- Voice
- SMS
- Percentage of traffic handled by small-cell sites vs traffic handled by macro-sites
- WACC
- Transit charges

In addition to the above, the following inputs will also be updated in the cost model by EC/Axon, by relying on the corresponding public sources:

- Inflation rates, extracted from the IMF[64].
- Nº of inhabitants per country, extracted from Eurostat[65].

[64] http://www.imf.org/external/datamapper/PCPIPCH@WEO/OEMDC/
[65] https://ec.europa.eu/eurostat/databrowser/view/tps00002/default/table?lang=en

7. Transit charges

7.1. Introduction

When a subscriber from country A (hereafter, the visiting operator) roams on a network in a different country B (hereafter, the visited operator), there are two differentiated services provided by the visited to the visiting operator.

First, the visited operator allows the visiting operator's subscribers to roam on its network, temporarily providing its mobile services to these customers while they roam on its network (i.e. voice calls, SMS and mobile broadband). The purpose of the cost model developed by Axon for the EC is to understand the costs of providing these wholesale services (including any wholesale commercial costs associated with these activities).

Second, in addition to the wholesale service just described, the visited network operator is also responsible for transiting the traffic originated by the roaming customer on its network to the network where the traffic is terminated. In the case of roaming customers, as typically these subscribers are outside of their country of origin when roaming, roaming traffic typically needs to be transited back to the country of origin of the roaming customer (e.g. a call from a roaming customer to a number in its country of origin will need to be transited to a terminating network in that country). For this, visited networks typically direct roaming traffic to a point of interconnection with international carriers and then pay a fee to an international transit carrier for transiting the traffic to its destination.

This means that any wholesale roaming price caps need to allow visited network operators to recover the costs of two differentiated services: (i) the wholesale network costs generated by the roaming customer (which are assessed in the Axon cost model) and (ii) any charges paid by the visited network to its international transit carrier for transiting the roaming traffic to the terminating network (which are not part of the cost model developed by Axon).

For the purpose of informing its decision on the appropriate wholesale roaming caps, the EC/Axon has analysed the transit payments made by visited telecoms operators when providing wholesale roaming services.

7.2. The approach followed by the EC to estimate transit charges

In line with the approach followed in the previous reviews of the roaming rules, the EC/Axon requested, as part of the data collection process of this project, information to operators on the transit charges they pay for wholesale roaming traffic. The information gathered shows significant variations in the charges provided by operators.

International transit charges are relevant for voice and data services:

- Voice services: when originating a call on a visited network operator, the originating operator interconnects with an international transit carrier of its choice that then routes the call to the terminating network operator; and
- Data services: data traffic needs to be routed back to the home network for real-time billing and measures for customer protection (e.g. to prevent bill-shock) and charging transparency.

In the following table, the EC presents a comparison of the transit charges considered in the previous 2019 roaming review[66] and the new prices calculated:

	Voice	Data
Estimates previous roaming review	0.5 EURcent/min	0.2 EUR/GB
Estimates current roaming review	0.4 EURcent/min	0.095 EUR/GB

Figure 7.1: Estimates of transit charges paid by wholesale roaming operators [Source: European Commission]

The estimates for the current roaming review are based on the information provided by operators in the data collection process of this project.

[66] For a description of the estimates of transit charges used in the previous review of the roaming rules, please see the EC's 2019 Report from the Commission to the European Parliament and the Council on the review of the wholesale roaming market, available here.

Annex A. Description of GISCO's classification of the degree of urbanisation

GISCO's definition of the degree of urbanization is performed based on the following criteria:

- *Densely Populated Areas:* At least 50% of the area is densely populated. This category is referred to in the model as 'URBAN' geotype.
- *Intermediate Populated Areas:* Less than 50% of the area is densely populated and less than 50% of the population is living in a rural area. This category is referred to in the model as 'SUBURBAN' geotype.
- *Thinly populated Area:* At least 50% of the population lives in rural areas. This category is referred to in the model as 'RURAL' geotype.

In order to define the percentage of an area that is considered to be densely populated, or rural, GISCO divides the LAU area in 1 km^2 and classifies them as follows:

- *High-density Cluster:* Contiguous cells with a density of population higher than 1,500 inh/km^2 and more than 50,000 habitants.
- *Urban clusters:* Contiguous cells with a density of population higher than 300 inh/km^2 and more than 5,000 habitants.
- *Rural:* Cells not considered in any of the cases above.