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Excellence in Business

Assessment of the cost of providing mobile telecom services in the EU/EEA countries – SMART 2017/0091

Methodological Approach Document

Axon Partners Group

18 February 2019

Contents

1. Introduction

The European Commission (hereinafter "EC") has commissioned Axon Partners Group Consulting S.L.U. (hereinafter "Axon Consulting" or "Axon") to carry out the "*Assessment of the cost of providing wholesale roaming services in the EU/EEA countries – SMART 2017/0091*" ('the Project').

As described during the Workshop 1, held on 10 April 2018 at the EC's headquarters, the EC deemed relevant to develop a new cost study to understand the costs of providing mobile services in EU/EEA countries. As part of this cost study, the Axon/EC team has developed a Bottom-Up cost model that calculates the costs of providing mobile services in the EU/EEA countries.

The first draft cost model developed by Axon was subject to a first consultation round of comments from stakeholders that ran from 29 October 2018 until 23 November 2019. The objective of this document is therefore twofold. First, to describe the methodological choices adopted in the cost model, including any changes made to address comments from stakeholders during the first consultation round. Secondly, to allow stakeholders to provide additional comments on Axon's modelling approach during the second consultation round that will run from 18 February to 15 March 2019.

This document includes:

- An overview of the main methodological approaches adopted in the development of the cost model (section 2).
- A description of the key inputs considered in the implementation of the model, describing how they have been produced based on the data reported by NRAs (section 3).
- 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 4).
- An overview of the approach followed by the EC to estimate transit charges (section 5).

In line with our approach during the first consultation round, each of these sections includes a set of questions for which we expect to receive stakeholders' feedback during the second consultation round. As we already gathered feedback on our methodological approach during the first consultation round, we have produced a new set of consultation questions for the 2nd consultation, focused on those areas that have remained open or where we consider additional feedback is necessary to understand stakeholders' views. In order to reply to these questions please use the Template for providing comments that the EC/Axon team have shared with NRAs in parallel to this methodological document. Additionally, a summary of the questions raised throughout the document is provided in section 6.

2. Methodological approach

The Commission Recommendation of 7 May 2009 on the "*Regulatory Treatment of Fixed and Mobile Termination Rates in the EU*"[1] 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 have been reinforced in the European Electronic Communications Code (EECC)[2].

The approach used in our cost study is 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.

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

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	▶ 2015-2025

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

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

[2] 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.

Additionally, the table below describes at a high level the methodological treatment given to other relevant elements of the cost model, following stakeholders' feedback received during Workshop 1 and the first consultation on the cost model:

Methodological aspect	Approach Adopted	Section
Volume forecasts	▶ Roaming traffic projections have been based on an assessment of roamers' usage patterns. ▶ The busy hour input has taken into account the different patterns exhibited by roaming services (when data has been provided). ▶ Two additional scenarios have been included to assess volume forecasts (aggressive and conservative), which constitute a sensitivity check on our base case scenario.	3.1.2
Allocation of joint and common costs	▶ Two cost allocation modules have been implemented: • *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 has been implemented.	N/A
Economic depreciation	▶ The implementation of economic depreciation is performed at asset level. ▶ Two alternative production factors have been considered and implemented, namely, based on (i) demand and (ii) revenues. ▶ The feedback provided by stakeholders in the first consultation round showed a preference for the demand-based economic depreciation.	2.3

Methodological aspect	Approach Adopted	Section
Seasonality	▶ The impact of seasonality has been assessed (when data has been provided). ▶ Based on the feedback received in the first consultation, two additional scenarios have been included to assess the impact of considering different thresholds to identify the existence of seasonality (10% and 30%). As per our findings (see presentation shared with stakeholders), we continue to believe that the 50% threshold is the most appropriate approach.	3.1.10
Unit Costs	▶ Based on stakeholder's feedback, the EC/Axon team recognises that unit costs for the access network elements may indeed depend on differing economic conditions in each Member State. Therefore, we now consider country-specific unit costs for these assets (compared to setting this unit costs based on EEA averages as in the 1st consultation).	3.1.6
Single-RAN	▶ A full Single-RAN deployment scenario has been considered.	N/A
VoLTE	▶ VoLTE has been considered in the model, with two VoLTE adoption scenarios: • *Based on VoLTE-ready handsets adoption*: The percentage of 4G voice traffic is determined based on the expected availability of VoLTE-ready handsets reported by NRAs. • *4G-only operator:* The reference operator is assumed to provide all services through a 4G network. ▶ The feedback provided by stakeholders in the first consultation round showed a preference for the "*Based on VoLTE-ready handsets adoption*" scenario.	2.1

Methodological aspect	Approach Adopted	Section
Spectrum	▶ Spectrum license costs have been set on a country basis and reflect the costs faced by MNOs. ▶ The amount of MHz per spectrum band has been defined to properly reflect the spectrum available in each country. ▶ The amount of spectrum available and its split per access technology varies over time as per the data reported by NRAs. ▶ Based on the feedback received during the first consultation, country-specific useful lives have been implemented for the spectrum-related CapEx to ensure alignment with the licenses' duration in each Member State.	3.1.6

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

During the first consultation we gathered stakeholders' views on the scenarios and assumptions used in the cost model. In order to address the comments from stakeholders received during the first consultation, we have considered it appropriate to expand some of the scenarios considered in specific areas of the cost model. In line with this, the subsections below describe the different scenarios that have been defined in the cost model:

- Modelling of VoLTE
- Definition of traffic split per technology forecast
- Economic depreciation
- Definition of increments under a LRIC cost standard
- Allocation of wholesale specific costs
- Cell Radii
- Traffic patterns and seasonal behaviours
- Domestic data demand forecasts

2.1. Modelling of VoLTE

Two VoLTE adoption scenarios have been implemented in the cost model:

- *Based on terminal adoption*: The migration pattern towards VoLTE is based on the adoption of VoLTE-ready handsets reported by NRAs (actual and expected for the forecasted period). Under this scenario, the traffic split per technology is set based on the option selected for the forecast of the traffic split per technology (described in section 2.2 below).
- *4G Operator*: A 4G-only operator that serves all demand (for voice, data and SMS services) through a 4G network is considered under this scenario. The scenarios described in section 2.2 below for the traffic split per technology forecast do not apply to this scenario, as all traffic is considered to be on the 4G technology.

Stakeholders can assess the results obtained under each scenario by selecting the desired option in the control panel of the model (see Annex 2 - User manual for further indications on how to run the model):

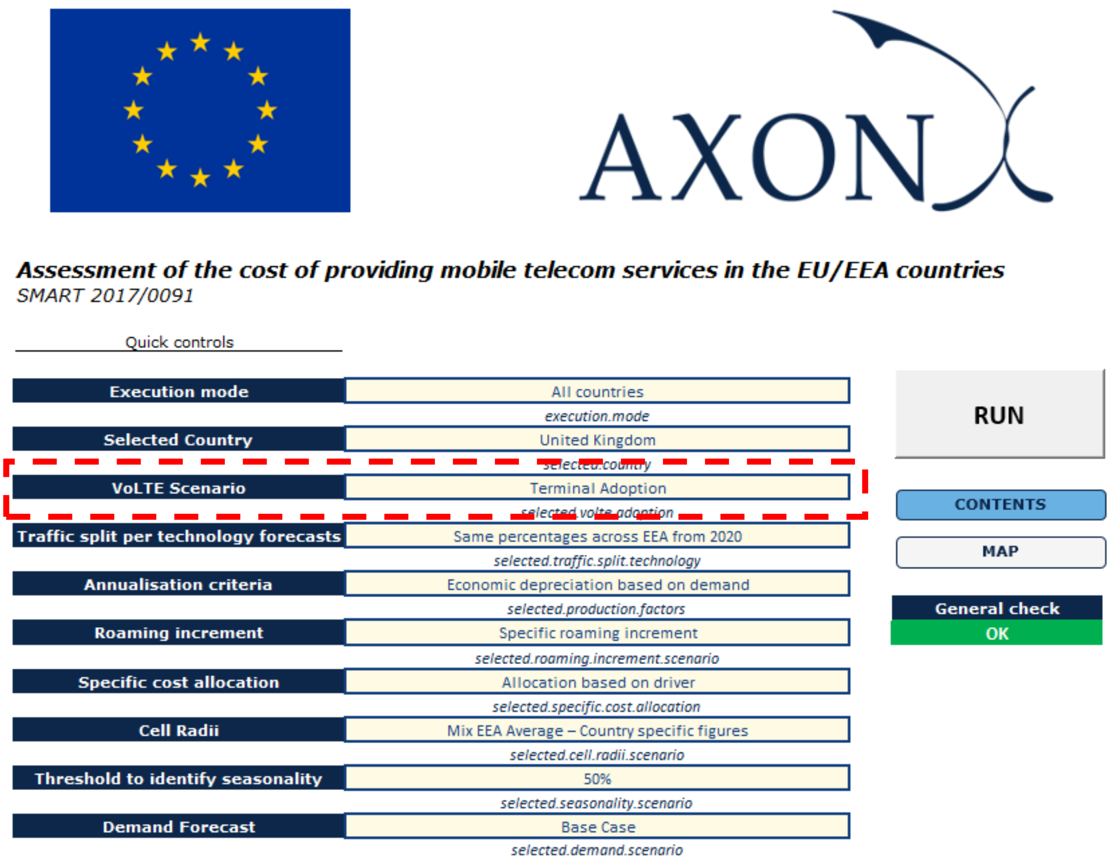

Exhibit 2.1: Selection of the alternative VoLTE adoption scenarios in the model [Source: Axon Consulting]

Decision: The feedback provided by stakeholders in the first consultation round showed a preference for the "Terminal adoption" scenario. The alternative scenario is included only for the purposes of conducting sensitivity analysis on the results.

2.2. Definition of traffic split per technology forecast

Following feedback received in the first consultation, a new scenario has been included to consider the possibility of setting the traffic split per technology forecasts beyond 2020 based on the historical trends at country level. Consistently, the following two scenarios for the traffic split per technology forecast are available in the model:

- *Same percentages across EEA from 2020*: Under this scenario, the same traffic split per technology is set for all EU/EEA countries from 2020 onwards[3]. This is the same approach adopted in the 1st draft model and is further described in section 3.1.8.3.
- *Country-specific projections*: In this case, the traffic split per technology forecasts are set at country level based on the information provided by stakeholders (when available and validated) or on a projection of historical trends. Section 3.1.8.3 also provides indications on how the inputs for this scenario have been calculated.

Note that the historical traffic split per technology (from 2015 to 2017) is always set based on the data originally provided by NRAs in the data collection process.

Stakeholders can assess the results obtained under each scenario by selecting the desired option in the control panel of the model (see Annex 2 - User manual for further indications on how to run the model):

[3] Please note that under this scenario the evolution from latest information available (2017) and 2020 target depends on the traffic split provided by stakeholders and the evolution in the past and, thus, it varies among Member States.

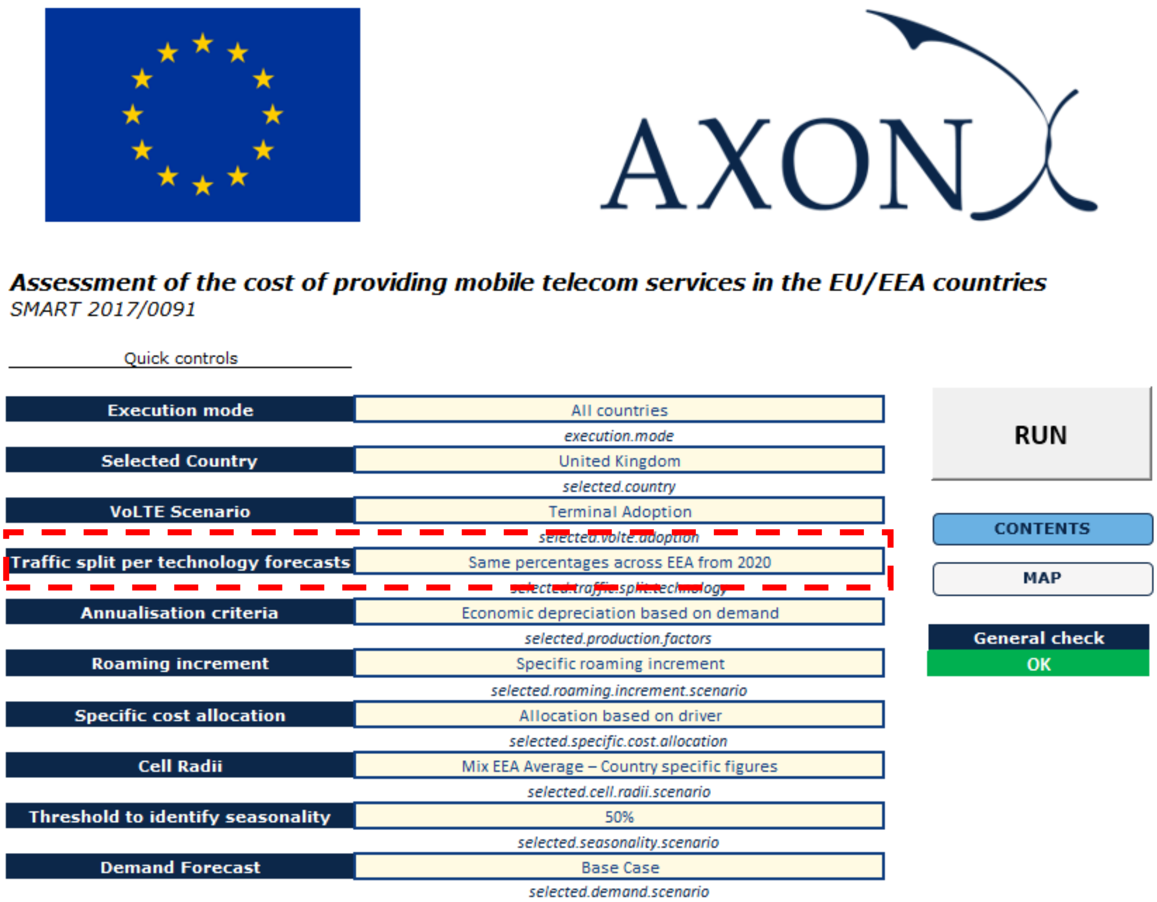

Exhibit 2.2: Selection of the alternative traffic split per technology scenarios in the model [Source: Axon Consulting]

The different scenarios for the traffic split per technology forecasts only apply when the "Based on terminal adoption" has been selected as the relevant VoLTE scenario.

Question 1: In your opinion, what scenario should be adopted to forecast the traffic split per technology? Please describe your preferred approach in detail and provide supporting information and references.

2.3. Economic depreciation

According to Hicks' classical approach[4], economic depreciation is the cost of maintaining the value of capital stock (that is, the level of wealth) constant between several periods. More generally, economic depreciation is defined as the difference between the period to period variation of the market value of an asset.

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

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

Where,

- d_i represents the annual depreciation cost
- O_i is the production factor of the asset
- 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

Given the lack of consensus identified in Workshop 1 with regards to the production factors to be considered in the implementation of economic depreciation, two alternatives were defined in the model to produce annual depreciation costs, 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.

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

Stakeholders can assess the results obtained under each scenario by selecting the desired option in the control panel of the model (see Annex 2 - User manual for further indications on how to run the model):

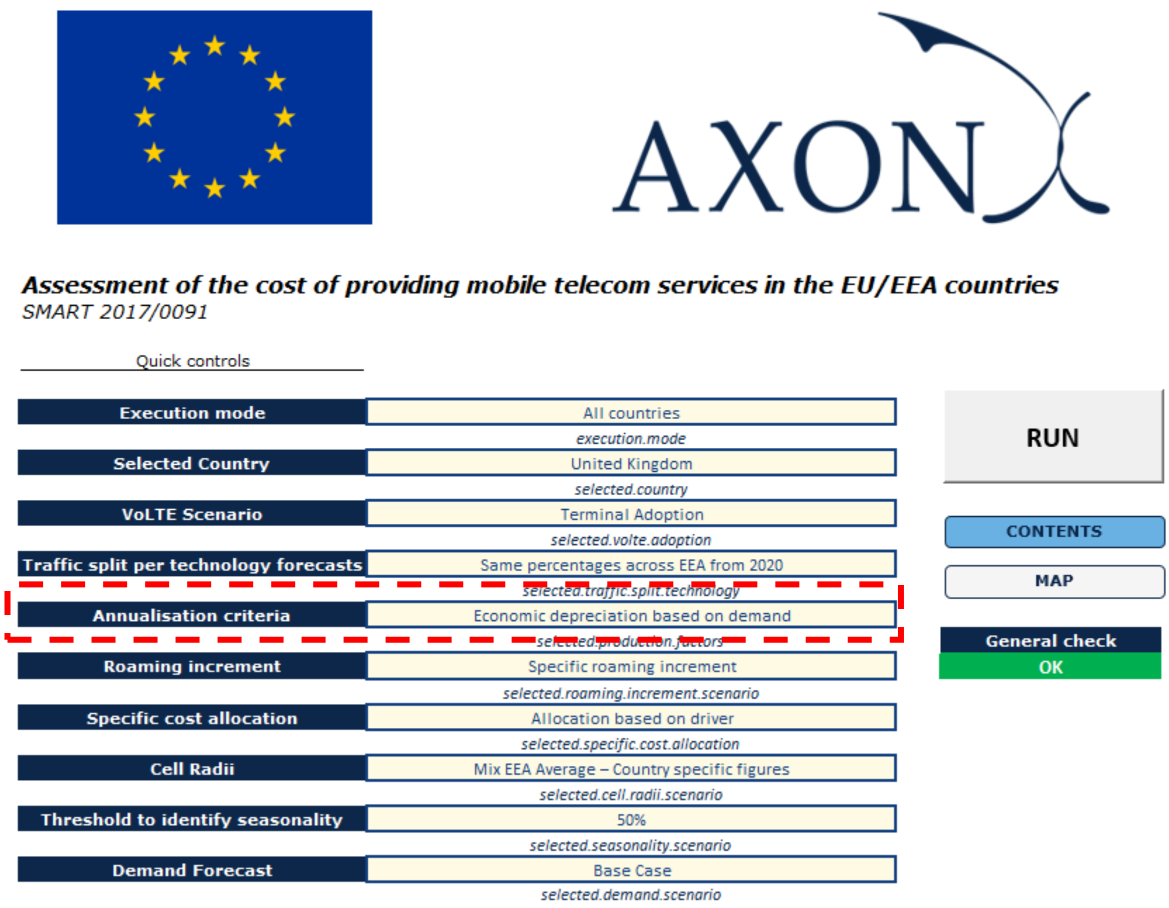

Exhibit 2.3: Selection of the alternative production factors to calculate the economic depreciation [Source: Axon Consulting]

Decision: The feedback provided by stakeholders in the first consultation round showed a preference for the "Demand" scenario. The alternative scenario is included only for the purposes of conducting sensitivity analysis on the results.

2.4. 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, the EC/Axon has identified two potential options to define the increments to be used in the cost 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.

Stakeholders can assess the results obtained under each alternative by selecting the desired option in the control panel of the model (see Annex 2 - User manual for further indications on how to run the model):

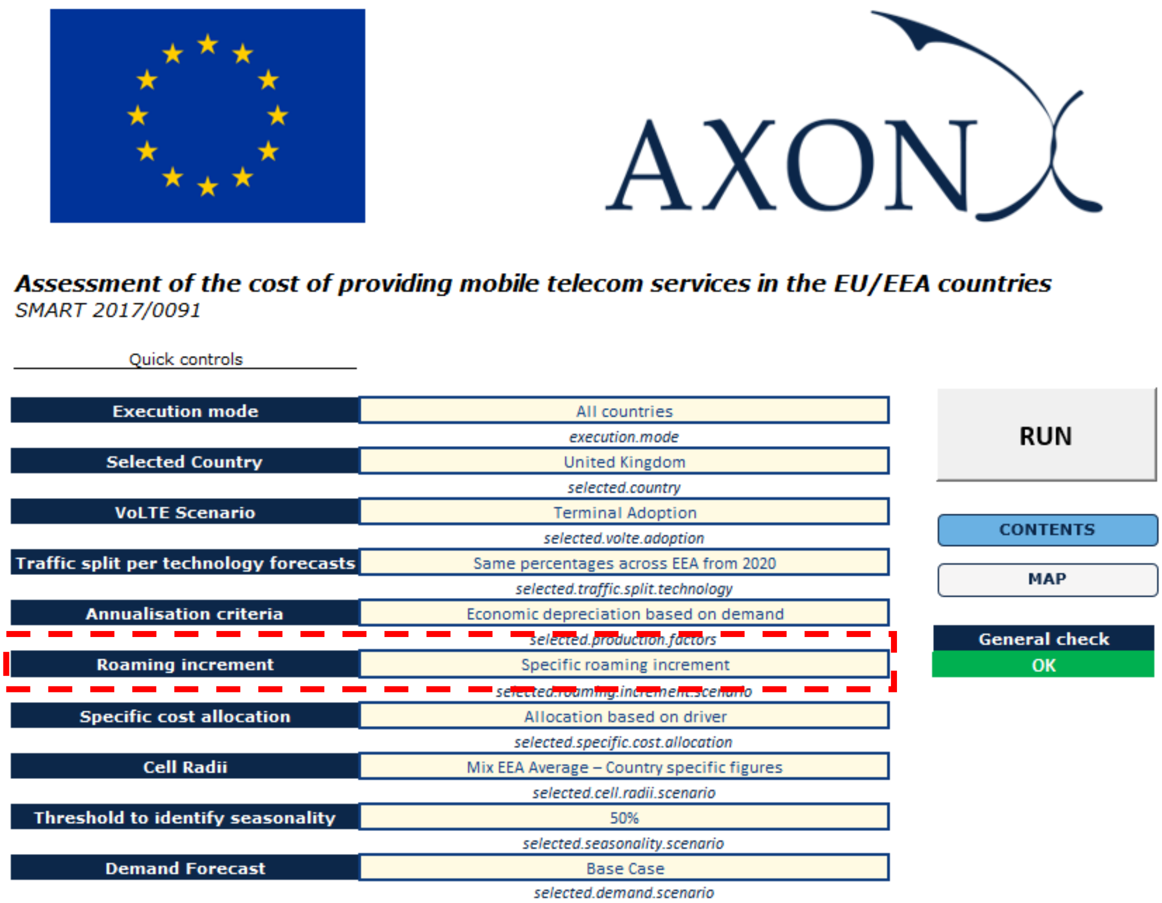

Exhibit 2.4: Selection of the increments to be considered in the model [Source: Axon Consulting]

Given that no clear preference was exhibited by stakeholders in the first consultation round (both options had approximately the same support), the EC/Axon is willing to gather stakeholders' feedback on this issue again in the 2nd consultation round.

Question 2: In your opinion, what option should be used in defining the increments considered in the model? Please, describe your preferred approach in detail together with its rationale, as well as provide supporting information and references.

2.5. 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 3.1.16 provides further indications on how these costs have been calculated and introduced in the cost model.

One of the key challenges in the treatment of these cost categories is the definition of the allocation criteria.

The EC/Axon team believes that these costs should be allocated to services that require a commercial wholesale interaction with third operators. In other words, these wholesale costs should be allocated across services spanning 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)

On the other hand, it is important to define the driver(s) that will be used to allocate wholesale specific costs to individual services. Two main alternatives were initially identified:

- *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 3.1.15.
- *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 3.1.15.

Stakeholders can assess the results obtained under each alternative by selecting the desired option in the control panel of the model (see Annex 2 - User manual for further indications on how to run the model):

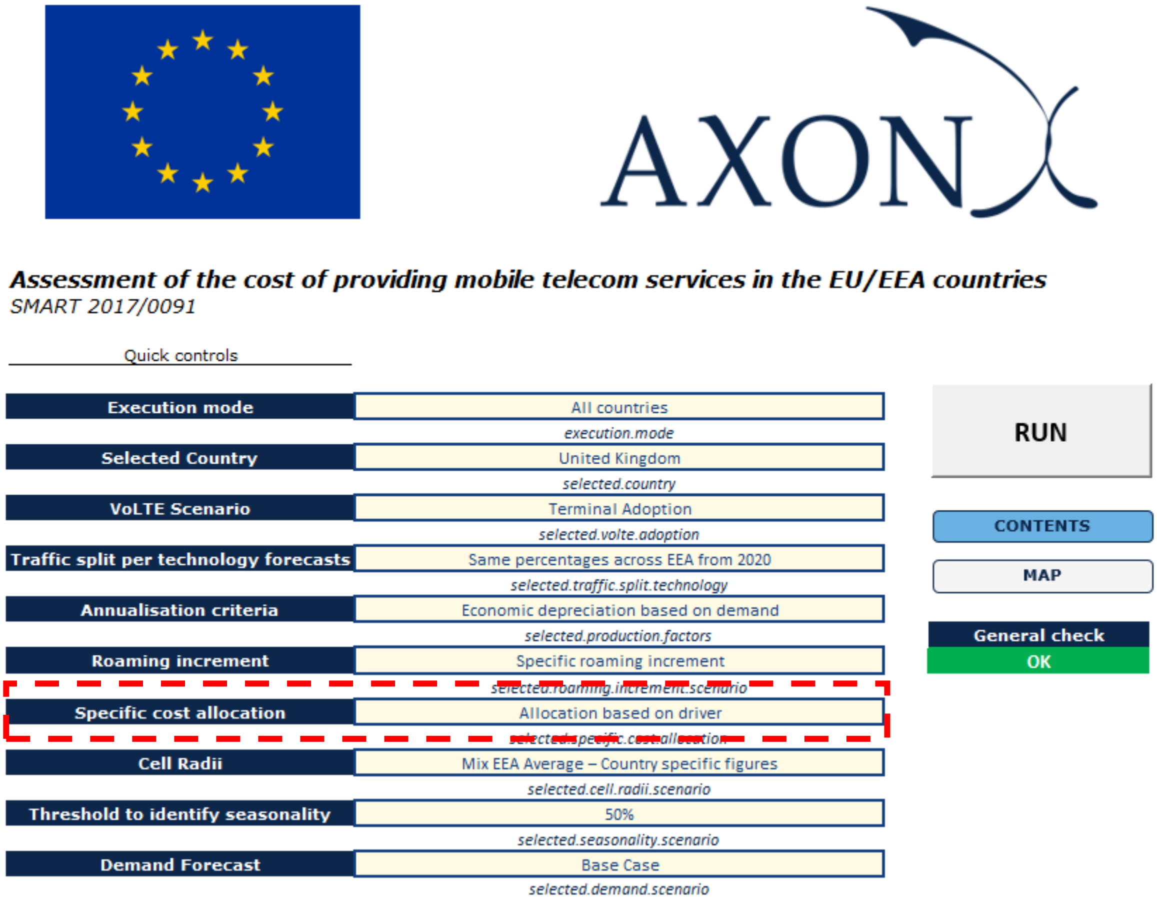

Exhibit 2.5: Selection of the alternative wholesale cost allocation options in the model [Source: Axon Consulting]

> **Decision**: The feedback provided by stakeholders in the first consultation round showed a preference for the "Allocation based on the drivers used in the regression analysis" scenario. The alternative scenario is included only for the purposes of conducting sensitivity analysis on the results.

2.6. Cell Radii

During the review of the data reported by stakeholders to the cell radii input we observed a high degree of variance, as illustrated in the figure below for the 900 MHz band:

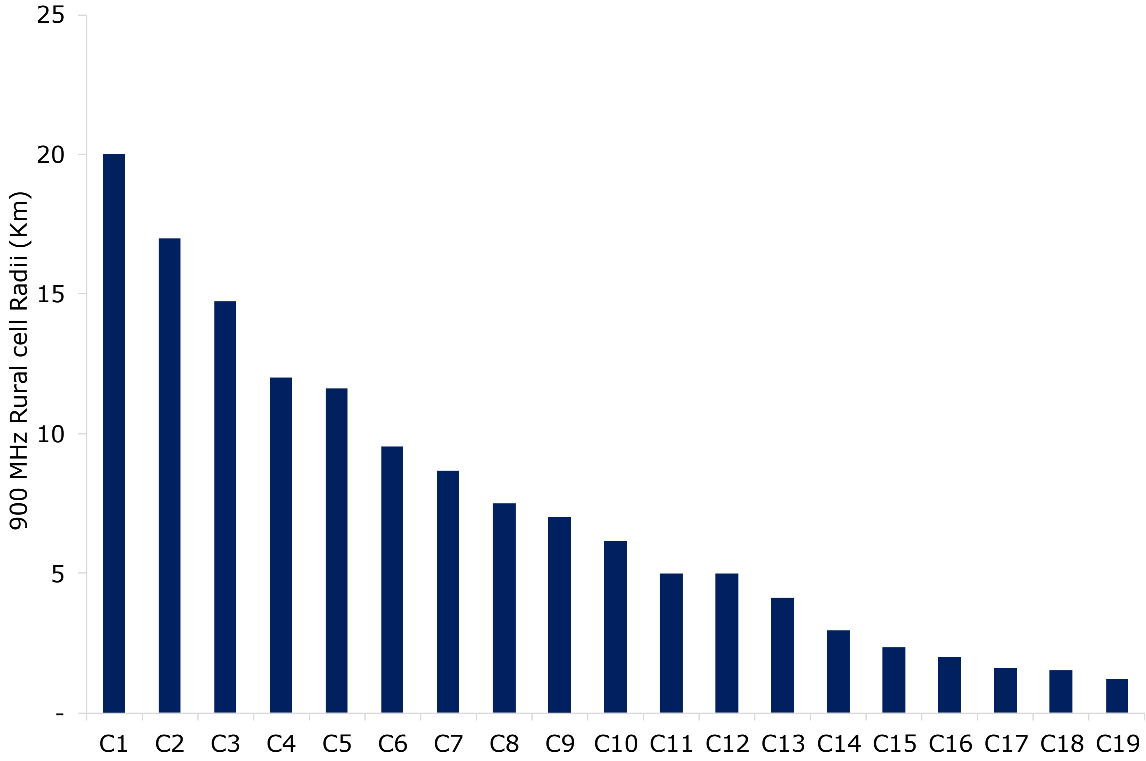

Exhibit 2.6: Maximum cell radius for the 900 MHz provided by different countries [Source: Axon Consulting]

While some degree of variation is expected due to geographical, demographical and technical constraints applicable in each Member State, in our view this does not explain the large differentials observed (for instance, in the exhibit above, the largest reference is 17 times higher than the smallest one). In addition to this, we have identified that the usage of the cell radii reported by stakeholders as-is leads to a mis-reconciliation in the number of sites obtained in some countries (further details about the approach adopted to assess the reconciliation of the model's results to MNOs' realities are presented in section 4).

The above situation made us conclude that the cross-country differences registered in the data reported by stakeholders was not due to country-specific factors, but to differing criteria in the way this information was actually reported by stakeholders.

Question 3: Do you agree that cell radii values in EU/EEA countries should be broadly consistent? If not, please describe in detail the factors that you believe could explain the large discrepancies observed in the figures collected from the different Member States.

In light of the situation discussed above, and based on the feedback received in the first consultation, we have defined the following two scenarios in the model:

- *Mix EEA Average – Country specific figures*: Under this scenario, while EEA averages are used for most countries, country-specific figures are considered when their differences with respect to EEA average values are reasonably justified. This approach is equivalent to that adopted in the first draft model and is further described in section 3.1.11.
- *Country specific figures only*: In this case, the cell radii figures provided by each NRA are considered for each country. Section 3.1.11 also provides indications on how the inputs for this scenario have been set.

Stakeholders can assess the results obtained under each scenario by selecting the desired option in the control panel of the model (see Annex 2 - User manual for further indications on how to run the model):

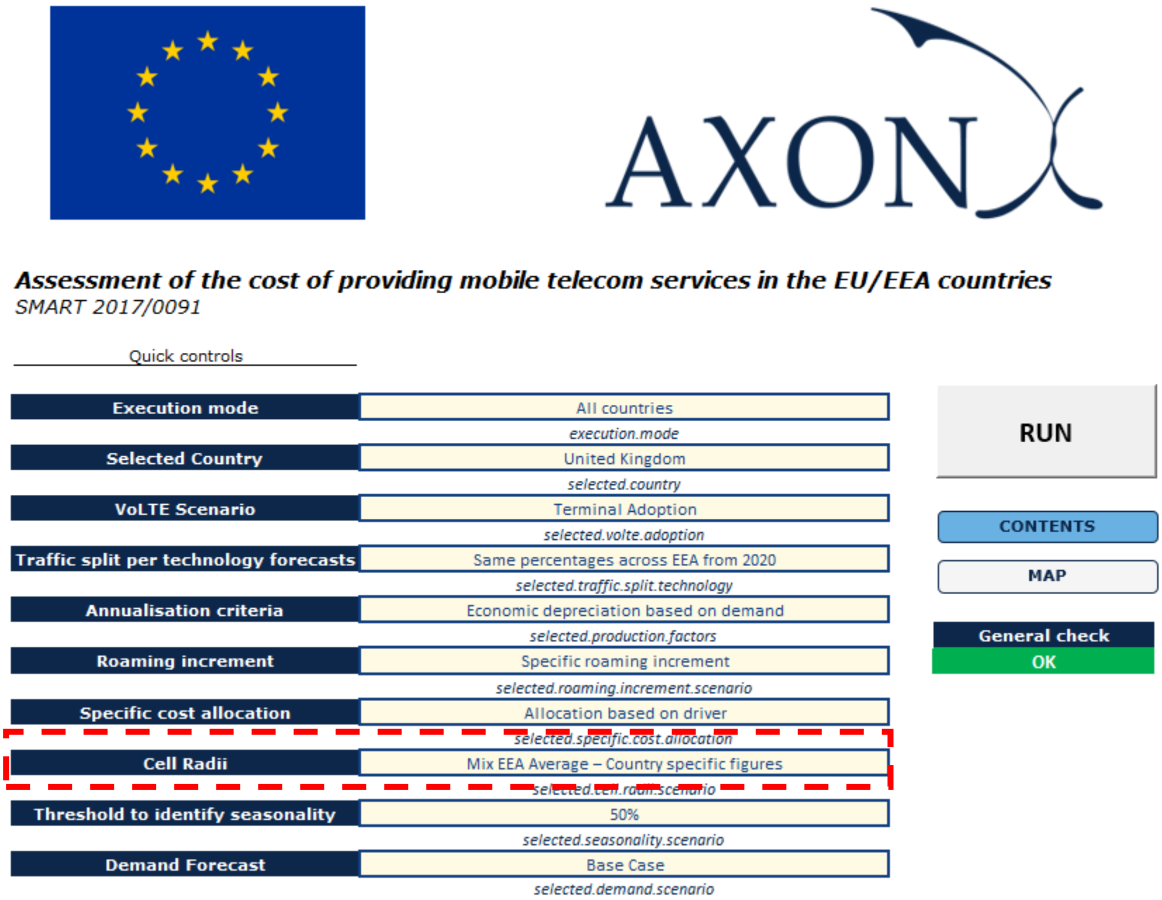

Exhibit 2.7: Selection of the alternative cell radii scenarios in the model [Source: Axon Consulting]

Question 4: In your opinion, what cell radii scenario should be adopted? Please justify your preferred approach in detail and provide supporting information and references for the preferred cell radii levels as well as the reconciliation in number of sites with real MNOs.

2.7. 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 2.8 illustrates, this approach is not representative of the more realistic situation experienced by mobile networks in most EEA countries:

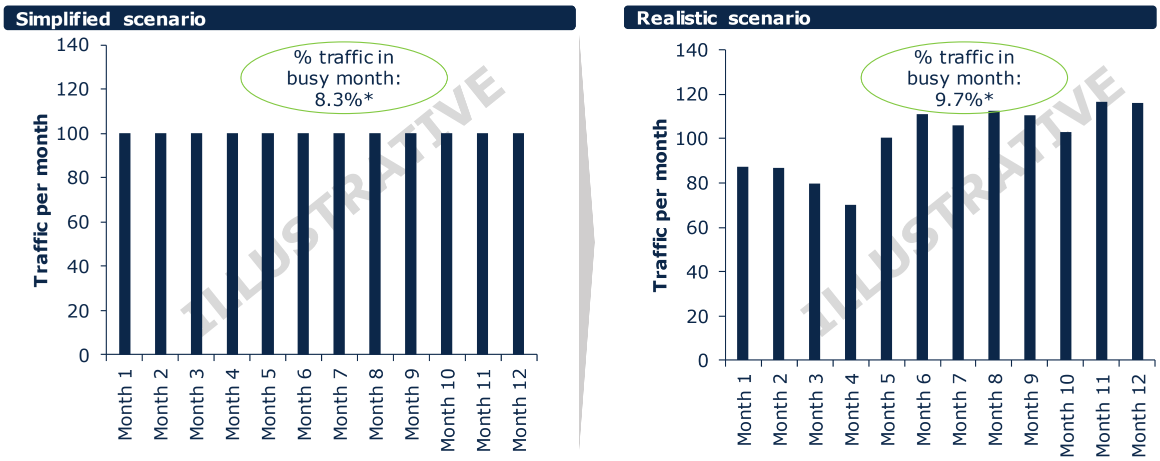

Exhibit 2.8: Comparison between a simplified and a more realistic (albeit dummy) traffic distribution scenario [Source: Axon Consulting]. Note: The percentage of traffic in the busy month presented in the two scenarios has been calculated as the traffic in the busy month divided by total traffic in the 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 have 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 has shown 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 have introduced new geotypes in the cost model[5].

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:

[5] Refer to section 3.1.16 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 our 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[6]
- 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[7]
- Preliminary assessment of seasonality (municipalities were preliminary classified as seasonal if the adjusted traffic in the busy month was at least 50%[8] higher than the yearly average). Based on the feedback received in the first consultation, new scenarios have been included to assess the impact of using different thresholds in this step (particularly, two thresholds of 10% and 30%, respectively). Nevertheless, we have observed that using a 10% threshold results in a mis-calibration of the model's results with respect to the realities of MNOs in these countries. In particular, we have observed that when using a 10% threshold the number of sites and the cost base of the modelled operator do not reconcile with MNOs' actual figures. In addition, we have observed that using a 30% threshold delivers virtually the same results as the 50% threshold for most countries. In light of these results, the EC/Axon consider that it would be appropriate to maintain the current 50% threshold as the main base case scenario. In any case, for the purposes of allowing sensitivity analysis on the model's results, a new drop-down list has been added in the COVER sheet of the model which allows stakeholders to run the model under the three different thresholds (note that these options are only available for the countries which provided enough information to assess their seasonal patterns).

[6] 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.

[7] This assumption is consistent with the approach adopted by the EC in the previous cost study, 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.

[8] We acknowledge that the definition of a rule to identify a municipality as being seasonal can be somewhat arbitrary. At one extreme, it could be argued that any municipality with a marginally greater than average traffic in a specific month of the year could be qualified as seasonal. The objective in choosing a 50% percentage is to ensure the significance of traffic seasonality on network design. That is, even though a more conservative rule (e.g. a lower percentage than 50% exceeding the annual average traffic) could have been used to identify a municipality as seasonal, we considered it important to use a rule that ensured that traffic seasonality would be likely to have a significant impact on the dimensioning of the network.

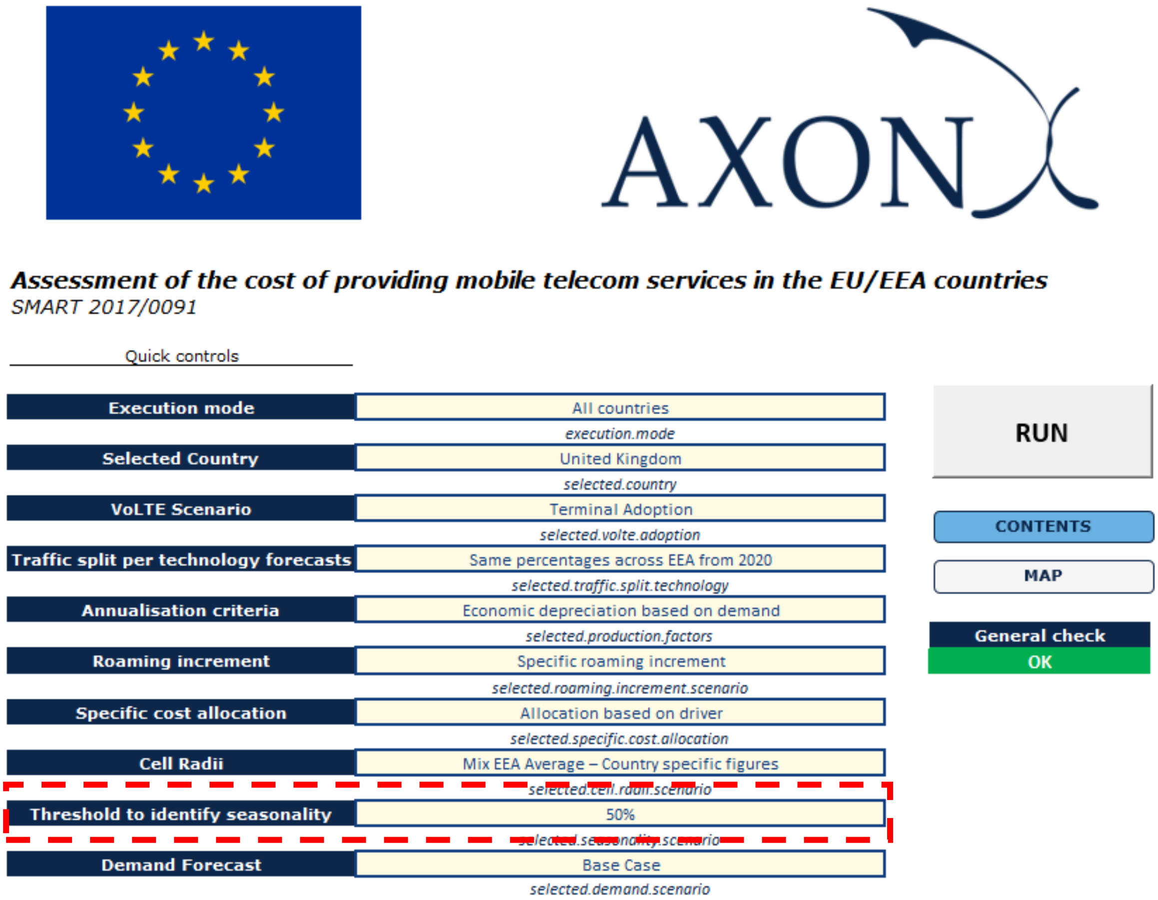

Exhibit 2.9: Selection of the alternative seasonality threshold scenarios in the model [Source: Axon Consulting]

- Phase 2: Assessment of the relevance of seasonality per geoytpe
  - Estimation of Jan-Mar 2017 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 FY2017 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. Additionally, NRAs that have submitted sufficient information to assess seasonality will also find an Excel file with the detailed calculations performed on their CIRCABC space.

Question 5: Do you consider appropriate to maintain as our base case scenario a 50% threshold to identify municipalities as seasonal (as described above), in line with the approach adopted in the first consultation? If you don't, please justify your position and provide supporting information and references.

2.8. 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 have been considered 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 is the base-case scenario that was already considered in the first consultation version of the model.
- *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 has been adopted in order to set the forecasts under each of these scenarios is thoroughly described in section 3.1.2.3.

Stakeholders can assess the results obtained under each scenario by selecting the desired option in the control panel of the model (see Annex 2 - User manual for further indications on how to run the model):

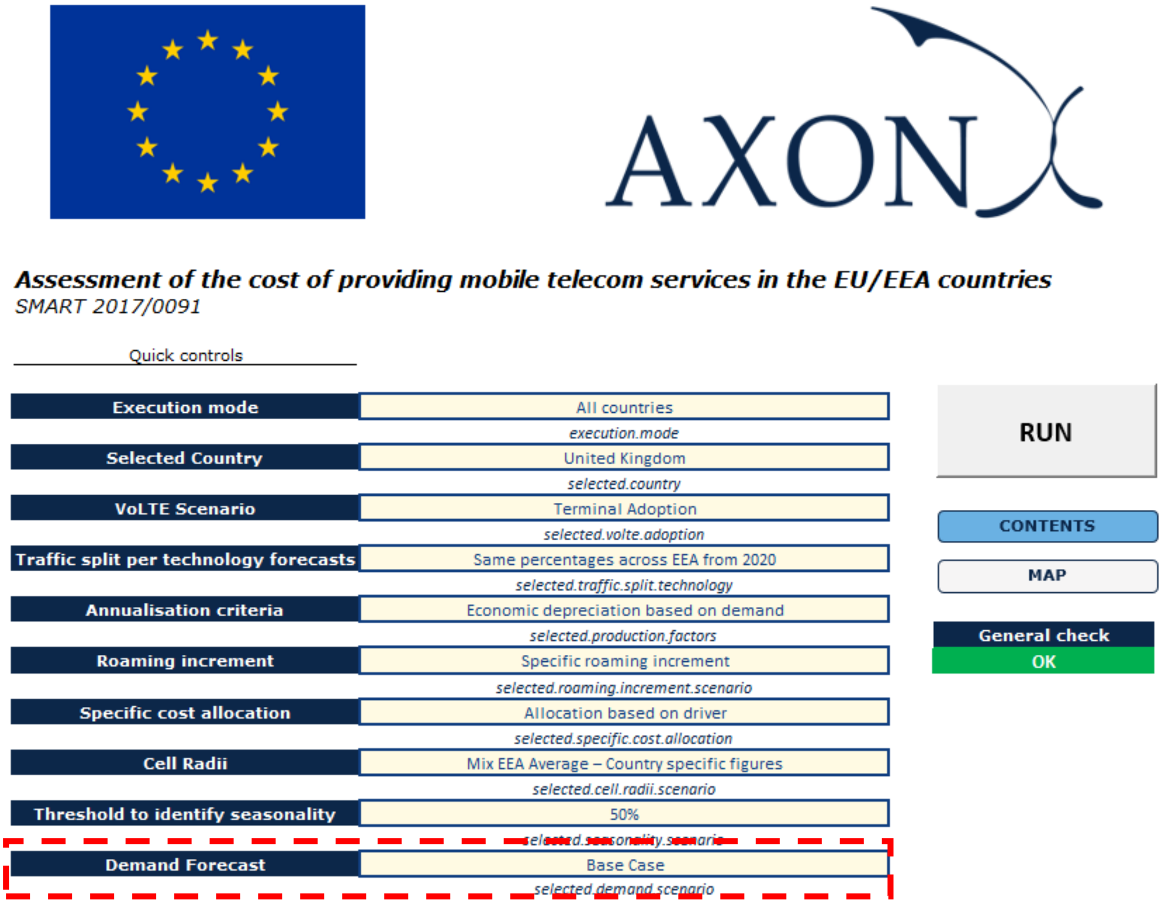

Exhibit 2.10: Selection of the alternative domestic data demand forecast scenarios in the model [Source: Axon Consulting]

> **Question 6:** In your opinion, what domestic data demand forecast scenario do you expect to better represent the traffic evolution in your country? Please, describe your preferred approach in detail and provide supporting information and references.

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 22 May until 2 July 2018) as well as additional publicly available information. In addition, further information submitted by stakeholders during the first consultation round has been considered in the definition of the inputs included in the second draft model. All the inputs considered in the cost model are thoroughly described in this section and have been split according to their source, as follows:

- Inputs gathered from stakeholders (Section 3.1)
- Geographical inputs from publicly available sources (Section 3.2)
- Standard industry inputs and low materiality inputs from publicly available sources (Section 3.3)

The subsections below include a number of questions for stakeholders regarding the inputs for which the general approach followed has been modified as a result of the 1st consultation process. Section 6 includes a summary of the said questions.

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 has been 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 draft Data Request Form and Manual were initially submitted to NRAs for comments on 27 April 2018.
- NRAs provided comments on 14 May 2018, which were thoroughly assessed by the EC/Axon team.
- Following treatment of the feedback received, the final Data Request Form and Manual were shared with NRAs on 22 May 2018.
- NRAs answered the Data Request before 2 July 2018.

- The EC/Axon team assessed the completeness and validity[9] of the information received and issued requests for clarifications and missing information on 14 July 2018.
- NRAs answered to the request for clarifications and missing information on 27 July 2018.

In addition to this, the additional data submitted by stakeholders as part of the first consultation round has been considered when populating the second draft model.

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

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	High	Medium
3.1.4	Coverage	High	High
3.1.5	Spectrum	High	Medium
3.1.6	Unitary Costs	High	High
3.1.7	General and Administration Expenses (G&A)	Medium	High
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	High
3.1.11	Cell Radii	Medium	Medium
3.1.12	Percentage of traffic in the busy hour	High	High
3.1.13	Backbone	Medium	medium
3.1.14	Useful Lives	High	High
3.1.15	WACC	High	High
3.1.16	Wholesale specific costs	Medium	Low

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

[9] See following subsections regarding the validation process.
[10] Assessed through cross-country comparisons with other NRAs' data and/or publicly available reports.

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 3.1.16.

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 to be 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). When the model is shared for public consultation, the inputs classified under this confidentiality level are not be shared with NRAs from other countries nor with the NRA from the subject country (e.g. to avoid national operators having access to information from other national operators). Therefore, this information has been anonymised or averaged before sharing the model.

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 have been 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 is to identify potential discrepancies between information provided by different NRAs beyond those that can be explained by country specificities. This type of validation exercise has been particularly relevant in the review of forward-looking projections.
- *Validation against Public sources*: Public sources such as spectrummonitoring.com[11], GSMA or BEREC 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.

NRAs have been involved in this validation process, for example, when issues have been identified with the information provided by an NRA during the verification process, clarifications have been 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 that were 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

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

Worksheet	Input 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 for the historical period. Depending on the scenario selected (see section 2.2), projections beyond 2020 are either based on a common EEA approach or on the historical trends at country 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	Depending on the scenario (see section 2.6) this can either be set at national level (i.e. country-specific approach) or based on EEA averages (some exceptions are described in section 3.1.11, for which this input has been defined at national level).
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 have been set at national level.
2H INP WACC	National 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. As defined in Workshop 1, the market share of the reference operator is to be set 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 was larger than 5, the market share of the reference operator was 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, EE, EL, ES, FI, FR, HR, HU, IE, IT, LT, LV, MT, NL, NO, PL, PT, RO, SE, SI, SK, UK
High-priority information provided	-
Not all high-priority information provided	-
No information provided	IS, LI, LU[12]

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

[12] As it will be observed throughout this document, IS, LI and LU 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, EE, ES, FI, HR, IE, IT, LT, LV, MT, NO, PT, SE, SI, SK
Confidentiality level 1	-
Confidentiality level 2	EL, FR, HU, NL, PL, RO, UK

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

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to 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 exceptions have been considered based on the feedback received in the first consultation round:

Country	Input adjusted	Issues identified	Approach adopted
SK	▶ Market share	The fourth MNO in the country heavily relies on National Roaming agreements with other MNOs	33.33% market share has been considered (as if there were 3 MNOs).

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

3.1.2. Demand

Traffic demand was defined at country level, per year and per service and 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 associated to each service variable 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

[13] Including free and invoiced traffic.

Service	Variable considered in the model
Domestic SMS - Incoming from international	SMS.International.Incoming.Wholesale.Incoming from international
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 past years (from 2015 to 2017) – referenced as historical demand -, as well as forecasts corresponding to future years (from 2018 to 2025) - referenced as forecast demand -.

The demand information is used to define the traffic requirements that the reference operator will need to face 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 addition, some NRAs took advantage of the first consultation round to update the demand information originally reported. The new information provided has been considered in the definition of the inputs of the second draft cost 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

[14] Eurostat's current population projections use 1st January 2015 population as base population and are produced for 29 European countries: all EU-28 Member States and Norway http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tps00002

subscribers into the future through the process described in the input definition section below.

- *International Roaming BEREC Benchmark Data Report*[15]*:* Information on traffic consumption of domestic and roaming services reported by BEREC. This data was used to validate the domestic traffic consumption reported by NRAs.
- *Eurostat Tourism Statistics – Nights spent at touristic accommodation establishments*[16]*:* 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	-	-	-	-
Not all high priority information available	BG, CZ, HU, LT, PL, SK, ES, SE	EL, HR, FR, DE, LV, MT, NL, SI	AT, BE, CY, FI, IE, NO, PT, RO, UK	
Not available		DK	EE, IT	IS, LI, LU

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

[15] BEREC Benchmark Report covers the period until Q3 2017: https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8011-international-roaming-berec-benchmark-data-report-april-2017-september-2017

[16] Eurostat Tourism Statistics 2017: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=tour_occ_ninat&lang=en

Data confidentiality

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

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

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to 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, in 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	AT, DK, PL, SI
Roaming inbound users from EEA[17]	BE, BG, CZ, CY, EL, ES, HU, LV, MT, NL, PL, PT, RO, UK
Roaming inbound users from Non-EEA[17]	BE, BG, CZ, CY, EL, ES, HU, LV, MT, NL, PL, PT, RO, UK
Data services	
Domestic Data	AT, BG, CY, DK, FR, LV, NL, PL, SK

[17] These services are not included in the model but have been adjusted to properly estimate the demand for other services (e.g. roaming traffic).

Service	Countries in which demand has been adjusted per market share
Roaming Data (EEA)	AT, BE, CY, DK, FR, NL, PL, RO, SK, UK
Roaming Data (Non-EEA)	AT, CY, DK, FR, NL, PL, RO, SK, UK
Voice services	
Domestic Voice – On-net	AT, CY, DK, EE, FR, HU, NL, PL, SK
Domestic Voice - Off-net to national	AT, CY, DK, EE, FR, NL, PL, SK
Domestic Voice - Off-net to international	AT, CY, DK, EE, FR, NL, PL, SK
Domestic Voice - Incoming from national	AT, BE, CY, DK, EE, FR, NL, PL, SK
Domestic Voice - Incoming from international	AT, BE, DK, EE, FR, MT, PL, SK
Roaming inbound Voice – Outgoing (EEA)	AT, CY, DK, EE, FR, NL, PL, RO, SK, UK
Roaming inbound Voice – Incoming (EEA)	AT, CY, DK, EE, FR, NL, PL, RO, SK, UK
Roaming inbound Voice – Outgoing (Non-EEA)	AT, BE, CY, DK, EE, FR, NL, PL, RO, SK, UK
Roaming inbound Voice – Incoming (Non-EEA)	AT, BE, CY, DK, EE, FR, NL, PL, RO, SK, UK
SMS services	
Domestic SMS – On-net	AT, CY, DK, EE, ES, FR, HU, NL, PL, SK
Domestic SMS - Off-net to national	AT, BE, CY, DK, EE, FR, NL, PL, SK
Domestic SMS - Off-net to international	AT, BE, CY, EE, FR, NL, PL, SK
Domestic SMS - Incoming from national	AT, BE, CY, DK, EE, EL, ES, FR, NL, PL, SK
Domestic SMS - Incoming from international	AT, BE, BG, CY, CZ, DK, EE, EL, ES, FR, MT, NL, PL, SK
Roaming inbound SMS – Outgoing (EEA)	AT, CY, DK, FR, MT, NL, PL, RO, SK, UK
Roaming inbound SMS – Incoming (EEA)	AT, BE, BG, CY, CZ, DK, EE, ES, FR, HU, LV, MT, NL, PL, RO, SK, UK
Roaming inbound SMS – Outgoing (Non-EEA)	AT, BE, CY, DK, ES, FR, MT, NL, PL, RO, SK, UK
Roaming inbound SMS – Incoming (Non-EEA)	AT, BE, BG, CY, CZ, DK, EE, ES, FR, HU, LV, MT, NL, PL, RO, SK, UK

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 180%). 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[18]. 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, EE, EL, ES, FR, HR, HU, IE, IT, LT, LV, NL, PL, PT, RO, SE, SI, UK	▶ 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 growth rates per service from 2015 to 2017 were analysed to identify potential unreasonable growth rates in the information provided

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

by NRAs. The following table summarizes the thresholds used to define which values where considered unreasonable:

Service	Nature of traffic	Minimum threshold	Maximum threshold
Data	Domestic	30%	140%
	EEA Roaming	150%	350%
	Non-EEA Roaming	80%	350%
Voice	Domestic	-5%	35%
	EEA Roaming	-5%	100%
	Non-EEA Roaming	-5%	100%
SMS	Domestic	-30%	30%
	EEA Roaming	-30%	30%
	Non-EEA Roaming	-30%	30%

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 to reflect typical average values across EU/EEA (obtained by averaging across the information provided by NRAs in other EU/EEA countries).

Country	Input adjusted	Issues identified	Approach adopted
BE	▶ Roaming Data (Non-EEA)	Non-EEA roaming data traffic was identified to be significantly higher than EEA roaming data traffic. For instance, in 2015 and 2016 the ratio between non-EEA and EEA data traffic was more than 1.20 (i.e. non-EEA roaming traffic was 20% higher than EEA roaming traffic) while the EEA average was approximately 0.25.	Data provided was considered inconsistent and was discarded. The input was obtained by multiplying the EEA roaming data traffic in BE by the EU/EEA average ratio between non-EEA roaming data and total roaming data traffic (EEA and non-EEA).

Country	Input adjusted	Issues identified	Approach adopted
SI	▶ Domestic Voice – On-net ▶ Domestic Voice - Off-net to national ▶ Domestic Voice - Incoming from national	Unrealistic growth rates observed for the three services between 2016 and 2017. For instance, off-net national traffic showed a growth of more than 75% between 2016 and 2017.	2017 voice traffic was adjusted to be equal to 2016's references (and aligned with 2015's).
	▶ Roaming inbound SMS – Outgoing (Non-EEA)	Unrealistic growth rate observed between 2016 and 2017 (more than 1,000% increase).	The figure provided for 2017 was discarded, and a new value was extracted from "Roaming inbound SMS – Outgoing (EEA)" traffic, by multiplying it with the EEA average ratio between non-EEA traffic and EEA traffic.

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.
- *BEREC Benchmark Report:* The traffic information per user and month for 2017 corresponding to domestic data, voice and SMS were cross-checked with the values reported in the International Roaming BEREC Benchmark Data Report. This comparison was intended to identify relevant inconsistencies in the 2017 traffic figures reported (cases above 100% or below 50% the figure included in BEREC's report).

  The following table summarises the adjustments performed on the reported data. In a nutshell, the EC/Axon team has not adjusted the values provided by NRAs when these are out of line with the publicly available information reported in the BEREC Benchmark Data Report. At the same time, while feedback was requested to stakeholders in the first consultation round, only a few provided their views on the differences detected below. Therefore, stakeholders from these countries are still invited to clarify the situations described below in their feedback to the second consultation materials.

Country	Input adjusted	Issues identified	Approach adopted
BE	▶ SMS domestic traffic	Domestic SMS outgoing consumption per user in 2017 was more than twice the value reported in BEREC's report.	The values provided by the NRA were preserved. No feedback was provided in the 1st consultation round and, therefore, the same approach has been preserved. Feedback is still welcomed from BE stakeholders on this issue.
EE	▶ Data domestic traffic	Data domestic traffic consumption per user in 2017 was more than twice the value reported in BEREC's report.	The values provided by the NRA were preserved. No feedback was provided in the 1st consultation round and, therefore, the same approach has been preserved. Feedback is still welcomed from EE stakeholders on this issue.
	▶ Voice domestic traffic	Domestic voice outgoing consumption per user in 2017 was more than twice the value reported in BEREC's report.	The values provided by the NRA were preserved. No feedback was provided in the 1st consultation round and, therefore, the same approach has been preserved. Feedback is still welcomed from EE stakeholders on this issue.
	▶ SMS domestic traffic	Domestic SMS outgoing consumption per user in 2017 was more than twice the value reported in BEREC's report.	The values provided by the NRA were preserved. No feedback was provided in the 1st consultation round and, therefore, the same approach has been preserved. Feedback is still welcomed from EE stakeholders on this issue.

Country	Input adjusted	Issues identified	Approach adopted
ES	▶ SMS domestic traffic	Domestic SMS outgoing consumption per user in 2017 was more than twice the value reported in BEREC's report.	The values provided by the NRA were preserved. No feedback was provided in the 1st consultation round and, therefore, the same approach has been preserved. Feedback is still welcomed from ES stakeholders on this issue.
MT	▶ Data domestic traffic	Data domestic traffic consumption per user in 2017 was one third of the value reported by BEREC.	MT clarified in its feedback in the first consultation round that the values initially provided to the EC/Axon team were indeed correct. Therefore, the values provided were preserved.
SI	▶ Data domestic traffic	Data domestic traffic consumption per user in 2017 was less than half the value reported in BEREC's report and in AKOS' market statistics report.	The value reported by BEREC was in line with the indicators presented by AKOS in its 2017 market report. Consequently, the value was adjusted to consider the actual information reported by the NRA in its official reports.
UK	▶ Data domestic traffic	Data domestic traffic consumption per user in 2017 provided initially was half the value reported by BEREC.	During the first consultation period UK revisited the information initially provided. New information is consistent with the value reported by BEREC and, therefore, it has been updated in the second draft model.

Table 3.13: Demand - Data validation – Historical demand – Validation of historical trends – BEREC Benchmark report [Source: Axon Consulting]

- *Roaming inbound roamers:* The number of roamer days corresponding to roaming inbound users from EEA and non-EEA countries were 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. No issues were identified.

- *Assessment of the comments provided by NRAs:* In some cases, NRAs highlighted specific and relevant comments in the spaces provided for this purpose in the information requests. These comments were assessed and the following issues were identified:

Country	Input adjusted	Issues identified	Approach adopted
EE	▶ Roaming inbound roamers - from EEA countries ▶ Roaming inbound roamers- from non-EEA countries	NRA stated that the data represented the number of roamers and not roamer days.	The average duration of a stay was assumed to be 3 days (rounded EEA average) to estimate the number of roamer days.
NL	▶ Roaming inbound roamers - from EEA countries for 2015 and 2016 ▶ Roaming inbound roamers - from non-EEA countries for 2015 and 2016	The values for 2015 and 2016 were only representative of 4% of the market while the value for 2017 was representative of 50% of the market. For 2015 and 2016, the adjustment by market share was not used as 4% was not considered enough to extrapolate the data for the whole market.	Values for 2015 and 2016 were rejected. On the other hand, the 2017 value was deemed correct as it was in the same range as the EEA average. 2015 and 2016 references were estimated by taking the value of 2017 and subtracting by the EEA average YoY growth of roaming Inbound EEA traffic, as shown below: $Traffic(i) = \frac{Traffic(i+1)}{1 + Growth(\%)}$

Table 3.14: Demand - Data validation – Historical demand – Inbound roamers [Source: Axon Consulting]

The historical traffic demand for all the services per year and per country was therefore validated through the multiple analyses described through 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
PT	• Roaming inbound Voice – Incoming - EEA • Roaming inbound Voice – Incoming – Non-EEA	The EEA and non-EEA traffic figures for roaming voice inbound incoming services were provided in a consolidated manner.	In all the cases, the consolidated information was provided under the Roaming Inbound EEA service. To disaggregate this information, the figure provided for each pair of services was multiplied by the percentage of inbound roamer days from EEA (as provided by PT NRA) divided by the total inbound roamer days to obtain the demand for the EEA related service. The non-EEA figure was calculated as the difference between the reported figure and the value calculated in the previous step.
	• Roaming inbound Voice – Outgoing - EEA • Roaming inbound Voice – Outgoing – Non-EEA	The EEA and non-EEA traffic figures for roaming voice inbound outgoing services were provided in a consolidated manner.	
	• Roaming inbound SMS – Incoming - EEA • Roaming inbound SMS – Incoming – Non-EEA	The EEA and non-EEA traffic figures for roaming SMS inbound incoming services were provided in a consolidated manner.	

Country	Input adjusted	Issues identified	Approach adopted
	▶ Roaming inbound SMS – Outgoing - EEA ▶ Roaming inbound SMS – Outgoing – Non-EEA	The EEA and non-EEA traffic figures for roaming SMS inbound outgoing services were provided in a consolidated manner.	
DK	▶ Domestic Voice – On-net and Domestic Voice - Off-to net national	The value reported for on-net traffic included the off-net traffic of one operator (hereinafter referred to operator C).	The adjusted voice on-net and voice off-net traffic has been calculated by assessing the split between on-net and off-net traffic for operator C as described below this table.
EL	▶ Domestic Voice - Incoming from national ▶ Domestic Voice - Incoming from international	2017 data for these two services was only representative of half of the year.	Both figures were multiplied by 2. The growth rate from 2016 to 2017 was cross-checked with other services to ensure the approach adopted was reasonable.
UK	▶ Domestic SMS – On-net ▶ Domestic SMS - Off-net national	The two inputs were provided in a consolidated manner (as off-net traffic).	The traffic provided was multiplied by the average EEA percentage of on-net SMS over on-net + off-net SMS to national to obtain the domestic SMS – on-net traffic. The domestic SMS – off-net to national traffic was obtained as the difference between the total traffic provided and the SMS domestic on-net traffic calculated above.

Table 3.15: Demand - Data treatment – Historical demand – Disaggregation of consolidated information [Source: Axon Consulting]

The formulas used for the estimation of on-net and off-net traffic in DK are presented below:

$$VoiceOnNet_{Adjusted} = VoiceOnNet_{original} \cdot \frac{Sum(MS)}{MS\ (Op\ A + Op\ B) + MS(Op\ C) \cdot \left(1 + EEARatio\ \left(\frac{Onnet\ Voice}{Offnet\ Voice}\right)\right)}$$

$$VoiceOffNet_{Adjusted} = VoiceOffNet_{original} + VoiceOnNet_{original} - VoiceOnNet_{Adjusted}$$

Where:

- MS is the market share of the operator.
- $Op\ A, Op\ B$ and $Op\ C$ are the different operators in the country

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:

- *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
BE	▶ Roaming Data (Non-EEA)	No data reported for 2015	Estimation based on average EEA roaming traffic trends (See indications below)
FI	▶ Roaming Data (EEA) ▶ Roaming Data (Non-EEA)	No data reported for 2015 and 2016	Estimation based on average EEA roaming traffic trends (See indications below)
IE	▶ Roaming Data (EEA) ▶ Roaming Data (Non-EEA)	No data reported for 2015	Estimation based on average EEA roaming traffic trends (See indications below)
PT	▶ Roaming Data (Non-EEA)	No data reported	Calculated as the product of intra-EEA roaming data demand in PT and the average ratio of Non-EEA to EEA roaming data traffic demand from reporting EEA countries

Table 3.16: Demand - Data treatment – Historical Demand – Estimation of missing information - Roaming data [Source: Axon Consulting]

In order to estimate a country's missing data in a specific year, we relied on average volume growth rates calculated as an average of the data from all countries that provided information to us. Particularly, two average growth rates were calculated, one for 2015-2016 and another one for 2016-2017. The average growth rates were calculated separately for EEA and Non-EEA roaming data. These average growth rates were then applied to the data reported by the particular country to estimate the missing information as per the formula presented below:

$$Traffic(year\ i-1) = \frac{Traffic(i)}{1 + Growth\%(i)}$$

- *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
FI	▶ Domestic Voice – Off-net to national ▶ Domestic SMS – Off -net to national	No data reported	Voice off-net to national was estimated to be equal to the voice incoming from national. SMS off-net to national was estimated as the product of voice off-net traffic to national and the average ratio between SMS off-net traffic to national and voice off-net traffic to national from reporting EEA countries. This ratio was calculated separately for each year (2015, 2016 and 2017).

Country	Input adjusted	Issues identified	Approach adopted
			2015 traffic was estimated by applying the 2016-2017 growth rate to the 2016 traffic.
NO	▶ Domestic Voice – Off-net to national ▶ Domestic SMS – Off- net to national	Domestic Voice – Off-net to national not reported for 2015. No data reported for Domestic SMS – Off-net to national	SMS off-net to national was estimated as the product of voice off-net traffic to national and the average ratio between SMS off-net traffic to national and voice off-net traffic to national from reporting EEA countries. This ratio was calculated separately for each year (2015, 2016 and 2017).
SI	▶ Domestic Voice – Off-net to national	No data reported	Voice off-net to national was estimated to be equal to voice incoming from national.

Table 3.17: Demand - Data validation – Historical Demand – Estimation of missing information - Voice and SMS off-net to national traffic [Source: Axon Consulting]

- *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
FI, NO	▶ Domestic SMS – On-net	No data provided	Estimated as the product of on-net voice traffic and the ratio between on-net SMS traffic and on-net voice traffic from reporting EEA countries. This ratio was calculated separately for each year (2015, 2016 and 2017)

Table 3.18: Demand - Data treatment – Historical Demand – Estimation of missing information – 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
DE	▶ Domestic Voice – Off-net international	No data reported for the year 2015	2015 traffic was estimated by applying the 2016-2017 growth rate to the 2016 traffic.
DK, UK	▶ Domestic SMS – Off-net international	No data provided	Estimated based on the product of SMS off-net to national traffic and the average ratio between the off-net to international and to national SMS traffic from reporting EEA countries.
FI, NO	▶ Domestic SMS – Off-net international	No data provided	Estimated based on the product of off-net voice to international traffic and the average ratio between SMS and voice traffic to international destinations from reporting EEA countries. Note that the approach adopted in this case differed from the cases above as FI and NO did not report the SMS off-net to national traffic.

Table 3.19: 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
FI, PT	▶ Domestic SMS – Incoming from national	No data provided	Considered to be equal to Domestic SMS - off-net to national.
NO	▶ Domestic Voice – Incoming from national ▶ Domestic SMS – Incoming from national	No data provided	Considered to be equal to Domestic Voice - off-net to national and Domestic SMS - off-net to national respectively.

Table 3.20: 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*

Different approaches were considered to estimate this input based on the availability of information (partially available or not available) as well as the robustness and representativeness of the results obtained. The following table summarizes the approaches adopted to estimate missing data:

Country	Input adjusted	Issues identified	Adopted approach
DE	▶ Domestic Voice – Incoming from international	Traffic was not reported for the year 2015	2015 traffic was estimated by deducting the 2016-2017 growth rate from the 2016 traffic.
IE	▶ Domestic Voice – Incoming from international	Traffic was not reported for the years 2015 and 2016	2015 and 2016 traffic were estimated by deducting the 2015-2016 and 2016-2017 average growth rates registered in other EEA countries from the 2016 and 2017 traffic, respectively.

Country	Input adjusted	Issues identified	Adopted approach
NO	▶ Domestic Voice – Incoming from international	No data provided	Estimated as the product of the voice incoming from national traffic in NO and the average ratio in the EEA countries between voice incoming from international and voice incoming from national traffic. This ratio was calculated separately for each year (2015, 2016 and 2017).
FI, NO, PT	▶ Domestic SMS – Incoming from international	No data provided	Estimated as the product of the voice incoming from international traffic in each country, and the average ratio in the EEA countries between SMS incoming from international and Voice incoming from international traffic. This ratio was calculated separately for each year (2015, 2016 and 2017). Domestic SMS incoming from national were not used as a reference for this estimation as it was not reported by any of these countries.
SI	▶ Domestic SMS – Incoming from international	Traffic was not reported for 2015 and 2016	2015 and 2016 traffic were estimated by deducting the 2015-2016 and 2016-2017 average growth rates registered in other EEA countries from the 2016 and 2017 traffic, respectively.

Table 3.21: 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:

<table>
<tr><th>Country</th><th>Input adjusted</th><th>Issues identified</th><th>Approach adopted</th></tr>
<tr><td>AT, FI, NO</td><td>- Roaming inbound Voice and SMS – Outgoing (EEA)
- Roaming inbound Voice and SMS – Incoming (EEA)
- Roaming inbound Voice and SMS – Outgoing (Non-EEA)
- Roaming inbound Voice and SMS – Incoming (Non-EEA)</td><td>No data provided</td><td rowspan="2">Roaming inbound traffic – Incoming or Outgoing- for both, SMS and voice, was estimated as the product of three factors:
- Ratio of inbound roaming data traffic (EEA or Non-EEA) over domestic data traffic
- Domestic traffic of the service -Voice or SMS-.
- EEA average ratio of inbound roaming traffic incoming or outgoing over total inbound traffic.</td></tr>
<tr><td>RO, SK, EE</td><td>- Roaming inbound SMS – Incoming (EEA)
- Roaming inbound SMS – Incoming (Non-EEA)</td><td>No data provided</td></tr>
<tr><td>BE</td><td>- Roaming inbound SMS – Outgoing (EEA) for all years</td><td>No data provided</td><td>Estimated as the product of roaming SMS inbound outgoing to Non-EEA countries from BE and the ratio of roaming SMS inbound incoming from EEA and roaming SMS inbound incoming from Non EEA from BE.</td></tr>
</table>

Country	Input adjusted	Issues identified	Approach adopted
DE, MT	▶ Roaming inbound SMS – Incoming (EEA) for 2015 ▶ Roaming inbound SMS – Incoming (Non-EEA) for 2015	Traffic was not reported for 2015	Estimated as the product of Roaming inbound SMS Incoming for 2016 from the country – DE, MT- and the ratio of Roaming inbound SMS outgoing for 2015 and Roaming inbound SMS outgoing for 2016 from the country –DE, MT-.
IE	▶ Roaming inbound SMS – Incoming (EEA) for all years ▶ Roaming inbound SMS – Incoming (Non-EEA) for all years	No data provided	Estimated as the product of roaming SMS inbound outgoing from IE and the ratio between roaming Voice inbound incoming and roaming voice inbound outgoing from IE.
RO	▶ Roaming inbound Voice – Incoming (Non-EEA)	No data provided	Estimated as the product of Voice roaming inbound EEA from RO and the ratio between voice roaming inbound Non-EEA and voice roaming inbound EEA from reporting EEA countries.

Table 3.22: Demand - Input validation – Historical Demand – Estimation of missing information - Incoming from roaming inbound traffic for voice and SMS [Source: Axon Consulting]

▶ *Roaming inbound users (EEA and non-EEA)*

The number of roaming inbound users was estimated based on the level of information available from each particular country as described in the table below:

Country	Input adjusted	Issues identified	Approach adopted
CZ, EE, ES, HU, IT, MT, UK	▶ Roaming inbound users – from EEA ▶ Roaming inbound users – from non-EEA	Information reported for 2017 only.	The 2017 figure reported by the NRA was divided by 1 + the average roamers growth rate in the reporting EEA countries to calculate 2015 and 2016 figures.

Country	Input adjusted	Issues identified	Approach adopted
AT, DE, DK, FI, FR, HR, NO, SE, SK	▶ Roaming inbound users – from EEA ▶ Roaming inbound users – from non-EEA	No data provided	Estimated as product of the following three factors: ▶ The number of nights spent at touristic accommodation ▶ The ratio between total inbound roamer days inbound and number of nights spent from EEA countries that did report information ▶ The split between EEA and non-EEA roamer days from countries that did report information.

Table 3.23: Demand - Input validation and treatment – Historical demand – Estimation of missing information - roaming inbound users [Source: Axon Consulting]

Input definition

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

Given that beyond IS, LI, LU who did not participate in this process, all NRAs provided historical demand information, no specific methodologies had to be defined to deal with more complex cases.

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 have been validated as well as how this input has been 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 7%, these were discarded from our exercise.

This implied that the references provided by HR, NL and PL had to be dismissed, as they all exhibited growth rates higher than 7% for a particular year.

The references provided by the remaining 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 2025 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 2018-2025 period was calculated as the product of 2017 subscribers and the population growth rates projected by Eurostat[19] for that period.

[19] Eurostat Population Projection:
http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tps00002

Validation and definition of domestic data traffic forecasts

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

Validation of data trends

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

- **Criterion A**: *Accelerating growth trend*. In some cases, we observed that some NRAs reported grow rates that increase 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 80% the forecast was discarded.
- **Criterion D**: *High growth rates beyond 2020*. While it is 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 2021 (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	Accepted?
AT	✗	✓	✓	✗	✗
BE	✓	✓	✓	✗	✗
BG	✓	✓	✓	✗	✗
CY	✓	✓	✓	✓	✓
CZ	✓	✓	✓	✓	✓
DE	✓	✓	✓	✓	✓
DK	NA	NA	NA	NA	NA
EE	NA	NA	NA	NA	NA
EL	✓	✓	✓	✓	✓
ES	✗	✓	✓	✓	✗
FI	✗	✓	✓	✗	✗
FR	✓	✗	✗	✗	✗
HR	NA	NA	NA	NA	NA
HU	✓	✓	✗	✓	✗
IE	×	✓	✓	✗	✗
IS	NA	NA	NA	NA	NA
IT	NA	NA	NA	NA	NA
LI	NA	NA	NA	NA	NA
LT	✓	✗	✓	✗	✗
LU	NA	NA	NA	NA	NA
LV	NA	NA	NA	NA	NA
MT	✓	✓	✓	✓	✓
NL	✗	✓	✓	✗	✗
NO	✓	✓	✓	✗	✗
PL	✓	✓	✓	✓	✓
PT	✗	✓	✓	✗	✗
RO	✗	✓	✓	✓	✗
SE	✗	✓	✓	✗	✗
SI	✓	✓	✓	✓	✓
SK	✓	✓	✓	✓	✓
UK	✓	✓	✓	✓	✓

Table 3.24: 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 national cost model. For those that did not met this validation, as shown in the exhibit below, we applied a common forecasting methodology:

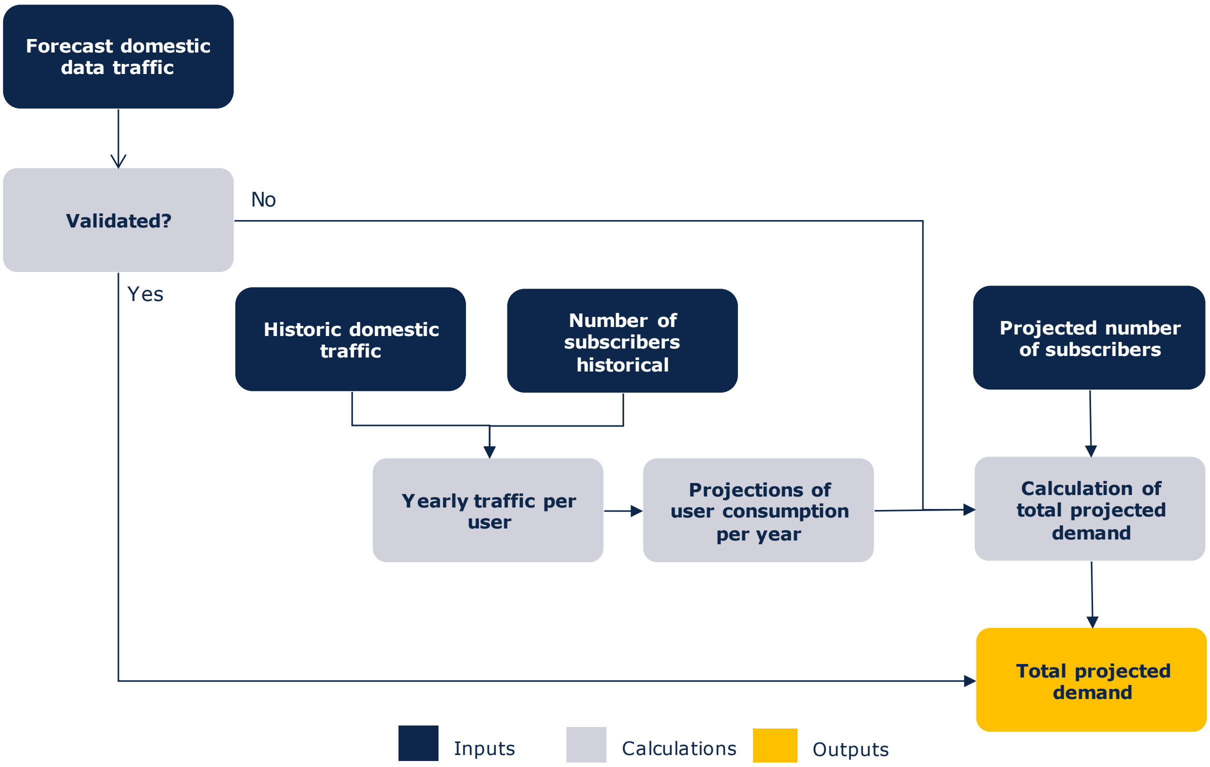

Figure 3.1: Demand – Input definition – Projection of domestic data traffic – YoY growth rate [Source: Axon Consulting]

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

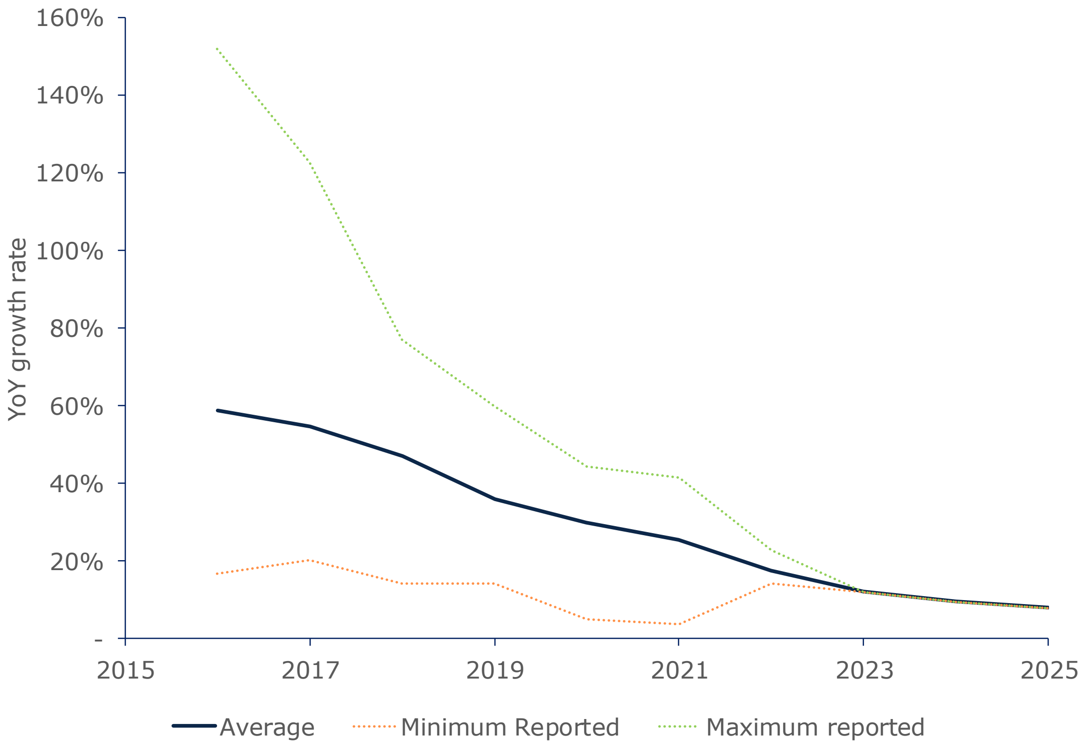

Exhibit 3.1: Demand – Analysis for the input definition – EEA average domestic data traffic YoY growth rate [Source: Axon Consulting from information provided by NRAs]

As the exhibit above shows, growth rates registered in mobile data traffic consumption per user are expected to decrease in the long term[20]. 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:

[20] This is a conclusion valid in the context of mobile networks that would hypothetically rely on 2G-3G-4G 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 5G networks may have on traffic.

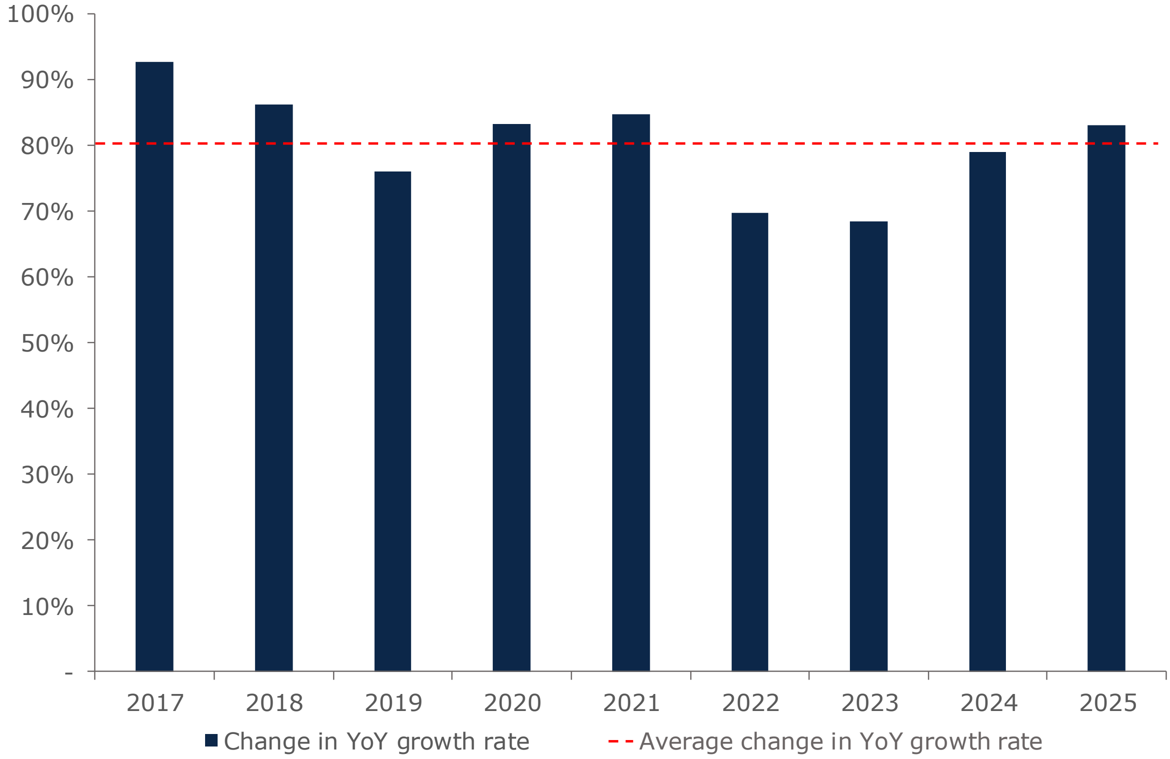

Exhibit 3.2: Demand – Analysis for the input definition –Change in YoY growth rates for the domestic data service [Source: Axon Consulting from information provided by NRAs]

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:

$$DataTraffic\ (year\ i) = DataTraffic\ (year\ i-1) \cdot (1 + 80{,}89\% \cdot YoYGrowthRate\ (i-1))$$

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.

It should be noted that when projecting the 2018 traffic we observed that in some countries the 2016-2017 growth rate was higher than that exhibited between 2015 and 2016 (i.e. it did not follow the common path presented in Exhibit 3.1). Consequently, and to avoid distorting the overall projection of data traffic in these cases, the annual growth rate between 2015 and 2017 was taken into consideration when calculating the 2018 projection.

For illustrative purposes, in the exhibit below we provide a graphical example of a domestic data consumption projection performed from 2018 to 2025, where the yearly traffic growth from 2018 onwards is always 80,89% of the traffic growth considered for the previous year. For the avoidance of doubt, this is just an illustrative example:

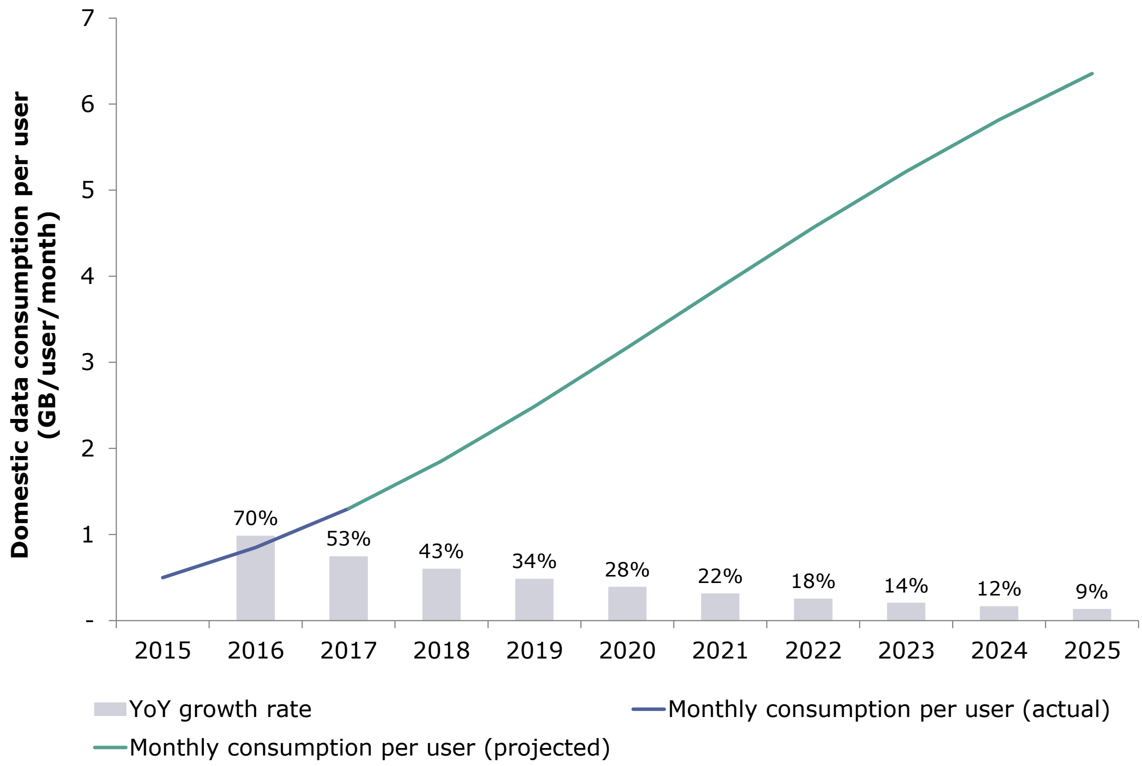

Exhibit 3.3: Demand – Input definition – Illustrative overview of the domestic data traffic projection performed [Source: Axon Consulting]

Please note that, as described in section 2.8., two alternative domestic data forecast scenarios have been introduced to assess the sensitivity of the model to the evolution of data traffic. These are described in detail at the end of this section.

Validation and definition of domestic voice and SMS forecasts

This section describes how the domestic voice and SMS trends provided by NRAs have been validated as well as how these inputs have been 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 have been 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:

$$Traffic\ (year\ i) = Traffic\ (year\ i-1) \cdot \min(1 + CAGR\ (2015-2017); 110\%)$$

With this formula, the annual growth rates registered in the past (between 2015 and 2017) 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 2018 to 2025, where the yearly traffic growth from 2018 onwards is always -2.5% in the example presented (equal to the annual traffic growth registered between 2015 and 2017 in this example). For the avoidance of doubt, this is just an illustrative example:

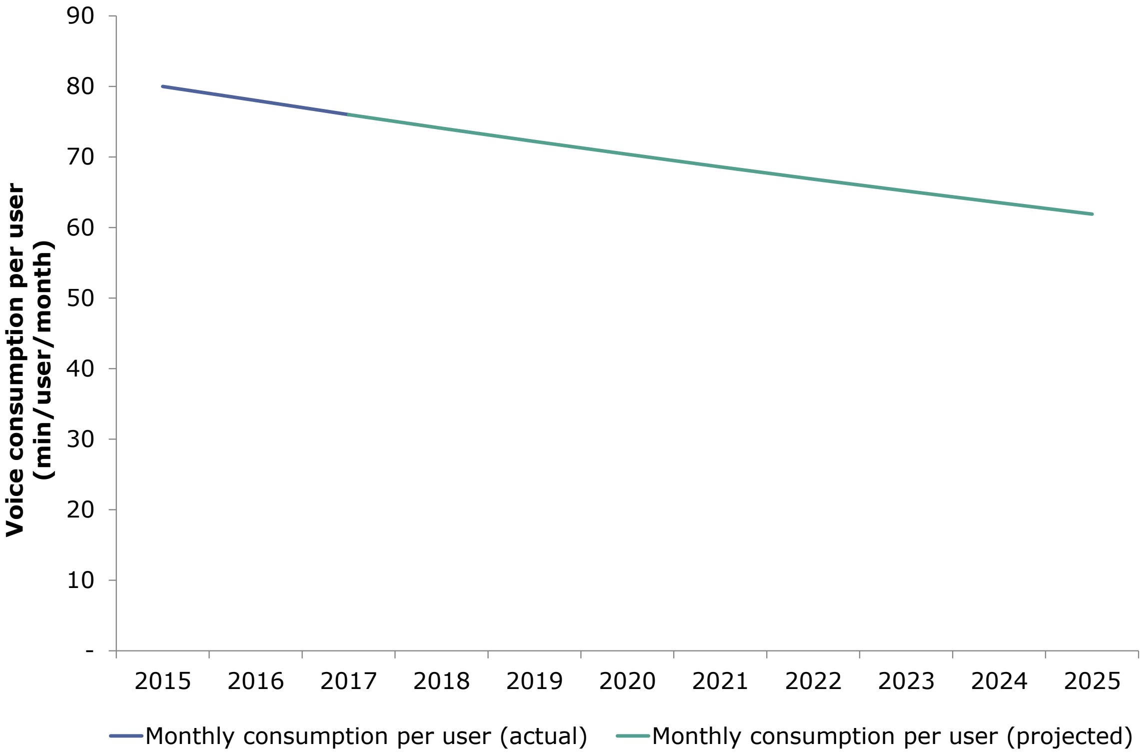

Exhibit 3.4: Demand – Input definition – Illustrative overview of the domestic voice traffic projection performed [Source: Axon Consulting]

Validation and definition of roaming data, voice and SMS forecasts

This section describes how the roaming data, voice and SMS trends provided by NRAs have been validated as well as how these inputs have been 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, especially after the introduction of the RLAH Regulation.

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 have been 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 projection of roamer days was performed recognising that they were expected to face three clearly differentiated growth cycles:

- Historical trends (2015 – 2017): The introduction of RLAH in 2017 contributed to a major increase in the number of roamer days per country. In this sense, historical trend volumes during 2015-2017 were still low given that RLAH was just recently introduced in June 2017.
- Transition period (2018 – 2019): Between 2018 and 2019 the number of roamer days is still expected to grow significantly as citizens become aware of the RLAH policy and get used to enabling roaming services while abroad. The number of roamer days experiences the greatest growth during this stage.
- Stabilisation (2020 - 2025): Once citizens become fully aware of RLAH, 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.

The growth rates of the first of these three stages (i.e. historical trends) are already known, as they were reported by NRAs.

With regards to the other two stages, we firstly defined the growth rates expected in the stabilisation phase. The growth rates expected for this period were made equal to the compounded annual growth rates registered in the number of nights spend in tourist accommodation from 2012 to the latest date available[21]according to Eurostat statistics. The exhibit below shows the overall projection of the number of nights spend in tourist accommodations across EEA countries, which experienced an annual growth rate of 4,4% in the period 2012-2016:

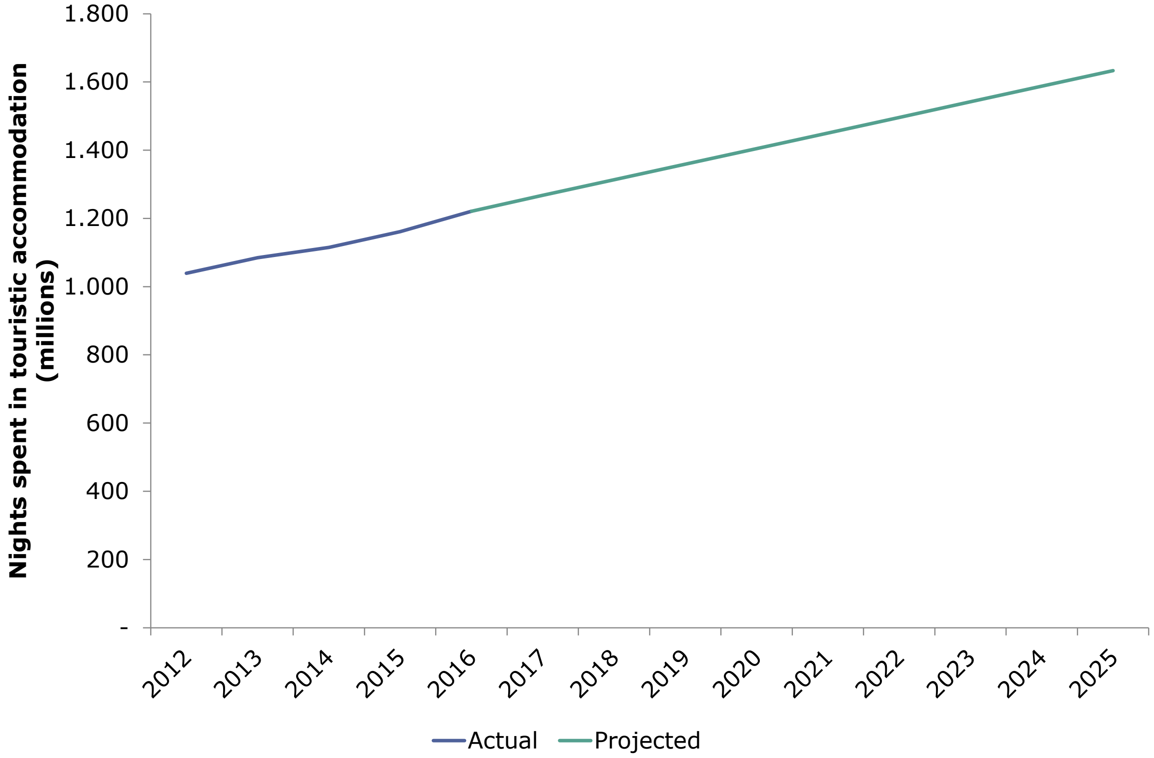

Exhibit 3.5: Demand – Input definition – Projection of the number of nights spend in tourist accommodation across EEA countries [Source: Axon Consulting based on Eurostat's data]. Note: Information reported does not include UK due to data unavailability.

Finally, the growth rates for the transition period were defined through the formula below:

$$\mathrm{GrowthRate(i) = GrowthRateNRA(2017) +}$$

$$\frac{\mathrm{GrowthRateEuroStats(2020) - GrowthRateNRA(2017)}}{3} \cdot \mathrm{(i - 2017)}$$

Where i represents the year for which the projection was performed (2018 or 2019).

The exhibit below illustrates the total number of roamer days in all EU/EEA countries, as reported by NRAs for the historical period (from 2015 to 2017, blue line), the expected

[21] For some countries data from 2017 was available while for some other countries the latest data available was 2016

number of roamer days during the transition period (from 2018 to 2019, green line) as well as the expected number of roamer days in the stabilisation period (from 2020 onwards, grey line):

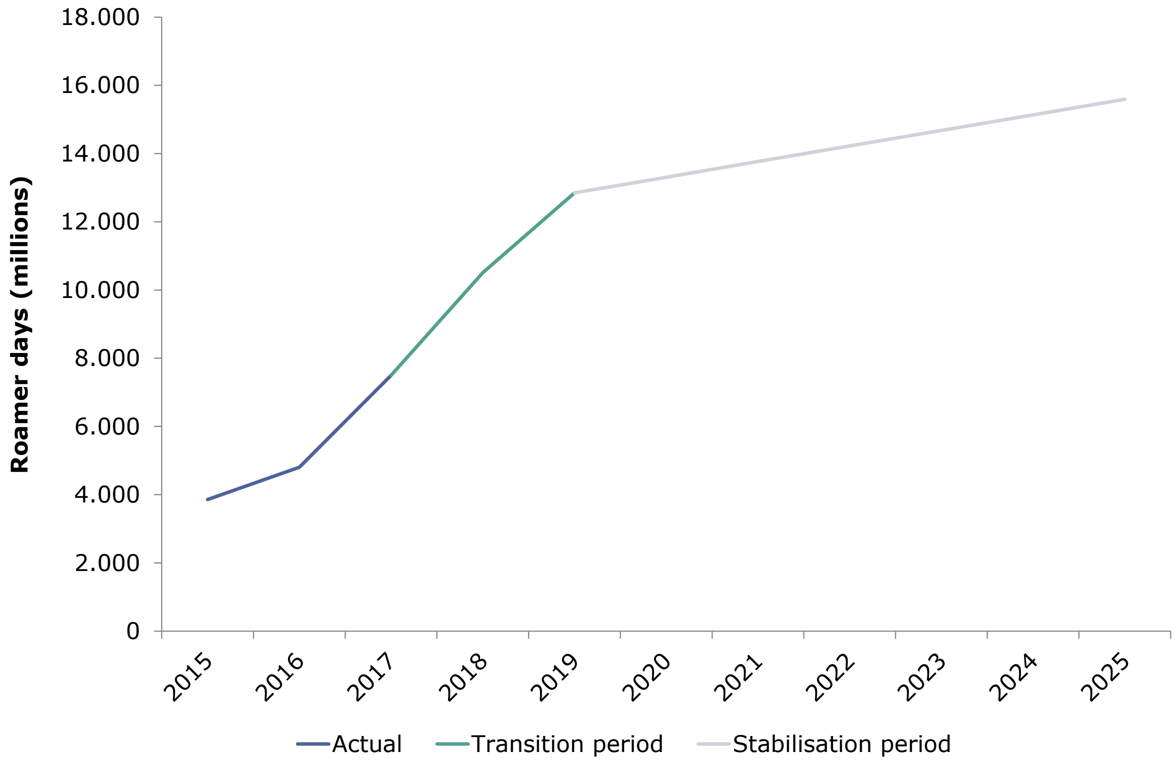

Exhibit 3.6: Demand – Input definition – Projection of the number of roamer days across EEA countries [Source: Axon Consulting based on NRAs' and Eurostat's data]

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

In the projection of the roaming consumption it is important to recognise that the extrapolation of historical trends could probably lead to unrealistic figures, given the steep impact just after the activation of the RLAH policy in 2017.

At the same time, it is true that upon the introduction of the RLAH regulation, the increase in roaming traffic consumption should be expected to follow the trends registered at domestic level. For instance, if a Croatian subscriber is expected to increase its data consumption by 50% YoY at domestic level, this same subscriber could also be expected to increase its data consumption at the same rate while roaming.

Therefore, 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. It is important to note that due to the lower growth observed among non-EEA services, when compared with the explosion in EEA roaming services after the application of RLAH, the mechanism above results in a significantly milder growth for non-EEA traffic in comparison with EEA traffic.

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.

The exhibit below shows the total demand of Roaming EEA inbound data traffic per country and year in PetaBytes (PB[22]). Only data for countries that have not marked this information as confidential is presented.

[22] 1 PetaByte (PB) equals 2^{50} bytes

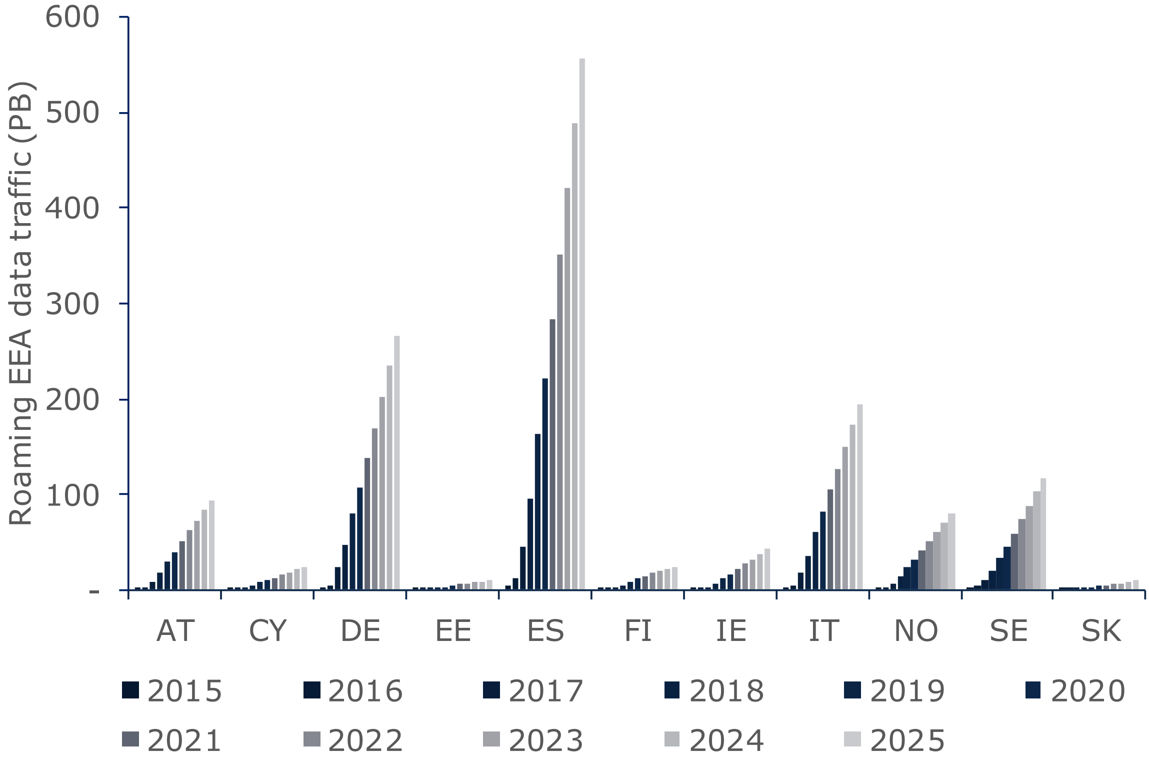

Exhibit 3.7: Demand – Input definition – Roaming inbound EEA data traffic per country and year [Source: Axon Consulting based on NRAs' data]

Definition of demand scenarios

As indicated in section 2.8, two alternative domestic data forecast scenarios have been introduced 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 have been 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 has been adopted to calculate the demand forecasts under each scenario, we have 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 have been defined as follows:

- Base Case scenario (β = 80,42%) as described in the "*Validation and definition of domestic data traffic forecasts*" section 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:

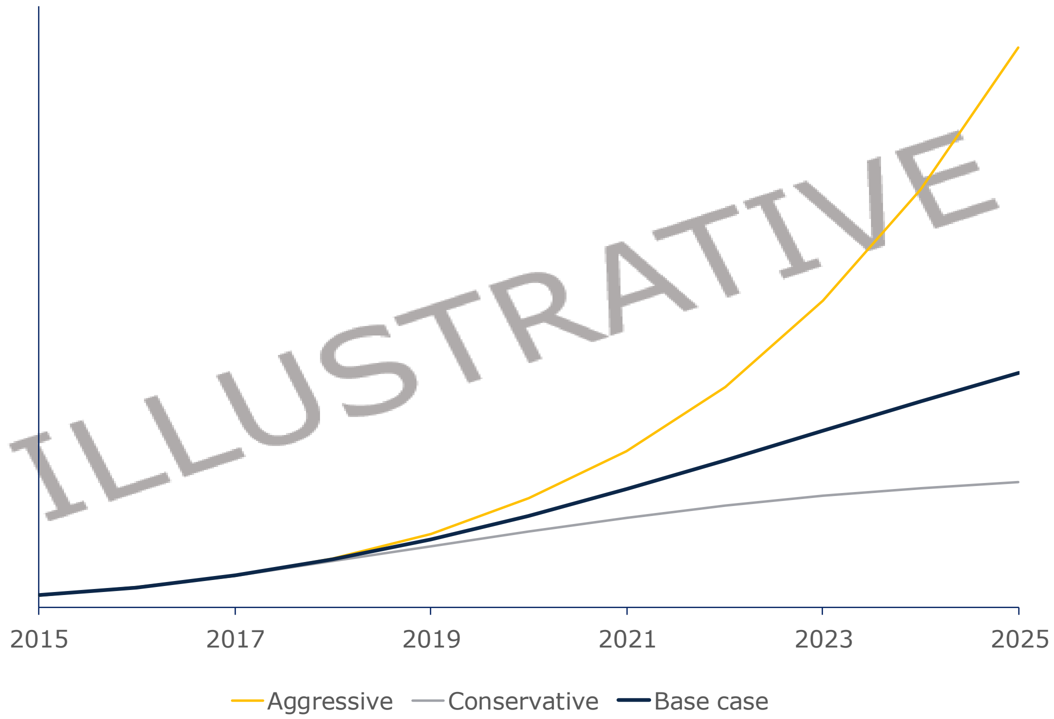

Exhibit 3.8: Demand – Input definition – Data forecast under different scenarios [Source: Axon Consulting based on NRAs' data]

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 have been used, no differences exist between these three scenarios).
- This sensitivity analysis also affects the calculation of roaming data projections as these are defined as a function of domestic data demand.

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	FR, HU, NO, UK
High-priority information provided	CY, EL, MT, NL, SK
Not all High-priority information provided	AT, BE, BG, FI, HR, CZ, DK, EE, DE, IR, IT, LV, LT, PL, PT, RO, SI, ES, SE
No information	IS, LI, LU

Table 3.25: Network Statistics - Data availability [Source: Axon Consulting]

Data confidentiality:

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

Table 3.26: Network Statistics - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to 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 have been 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
ES	▶ Uncompleted Calls Over Total Calls Percentage – Busy for domestic national ▶ Uncompleted Calls Over Total Calls Percentage – Busy for domestic international	Identified to be significantly higher than the EEA average	Values discarded.
NO	▶ Uncompleted Calls Over Total Calls Percentage – Busy for domestic national ▶ Uncompleted Calls Over Total Calls Percentage – Not Taken for domestic national	Identified to be significantly higher than the EEA average	Values discarded.
UK	▶ Uncompleted Calls Over Total Calls Percentage – Busy for domestic national voice service	Identified to be significantly higher than the EEA average	Value discarded.

Table 3.27: 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[23]
Uncompleted calls over total calls percentage - busy	Domestic national	AT, BE, HR, EE, FI, DE, EL, HU, IE, LV, LT, NO, PT, SK, SI, ES, SE, UK
	Domestic international	AT, BE, DK, EE, FI, FR, DE, EL, HU, IE, LV, LT, NO, PT, SK, SI, ES, SE, UK
	Roaming in Voice (EU/EEA)	AT, BE, BG, EE, FI, FR, DE, EL, HU, IE, LV, LT, NO, PT, SK, SI, SE, UK
	Roaming in Voice (Non-EU/EEA)	AT, BE, BG, CY, EE, FI, FR, DE, EL, HU, IE, LV, LT, NO, PT, SK, SI, SE, UK
Uncompleted calls over total calls percentage - not taken	Domestic national	AT, BE, DK, EE, FI, FR, DE, EL, HU, IE, LV, LT, NO, PT, RO, SK, SI, SE, UK
	Domestic international	AT, BE, DK, EE, FI, FR, DE, EL, HU, IE, LV, LT, NO, PT, RO, SK, SI, SE, UK
	Roaming in Voice (EU/EEA)	AT, BE, BG, DK, EE, FI, FR, DE, EL, HU, IE, LV, LT, NO, PT, RO, SK, SI, SE, UK
	Roaming in Voice (Non-EU/EEA)	AT, BE, BG, CY, DK, EE, FI, FR, DE, EL, HU, IE, LV, LT, NO, PT, RO, SK, SI, SE, UK
Average call duration	Domestic national	AT, BE, DK, EE, FI, EL, HU, LV, LT, SI
	Domestic international	AT, BE, BG, DK, EE, FI, EL, HU, LV, LT, NO, SI, UK
	Roaming in Voice (EU/EEA)	AT, BE, BG, DK, EE, FI, EL, IE, LV, LT, NO, SI, SE, UK
	Roaming in Voice (Non-EU/EEA)	AT, BE, BG, CY, DK, EE, FI, FR, EL, IE, LV, LT, NO, PT, SI, SE, UK

[23] 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[23]
Average ringing time	Domestic national	AT, BE, BG, CY, DK, EE, FI, EL, HU, IE, IT, LV, LT, NO, PT, SK, SI, SE
	Domestic international	AT, BE, BG, CY, DK, EE, FI, FR, EL, HU, IE, IT, LV, LT, NO, PT, SK, SI, SE, UK
	Roaming in Voice (EU/EEA)	AT, BE, BG, CY, DK, EE, FI, FR, EL, HU, IE, IT, LV, LT, NL, NO, PT, SK, SI, SE, UK
	Roaming in Voice (Non-EU/EEA)	AT, BE, BG, CY, DK, EE, FI, FR, EL, HU, IE, IT, LV, LT, NL, NO, PT, SK, SI, SE, UK

Table 3.28: 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 have been 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

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%. No issues were detected.
- *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

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

Country	Input	Issues identified	Adopted approach
CY	▶ GSM traffic % ▶ UMTS traffic % ▶ LTE traffic %	Reported download traffic percentage for all the technologies was significantly below the EEA average.	Value discarded.
FR	▶ GSM traffic %	Reported download traffic percentage for GSM was significantly above the EEA average.	Value discarded.
NO	▶ GSM traffic %	Reported download traffic percentage for GSM was significantly below the EEA average.	Value discarded.

Table 3.29: 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[24]
Download percentage for 2G data traffic	CY, EE, FR, IS, LI, LU, NO
Download percentage for 3G data traffic	CY, EE, IS, LI, LU
Download percentage for 4G data traffic	CY, EE, IS, LI, LU

Table 3.30: Network Statistics - Input Definition – Data statistics [Source: Axon Consulting]

[24] 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, and 4G) 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 has been 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[25] 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	CY, EE, FR, MT, NL, NO, UK
High-priority information provided	BE, BG, HR, CZ, DK, FI, DE, EL, HU, IT, LT, PL, RO, SK, SI, ES, SE
Not all High-priority information provided	AT, IE, LV, PT
No information	IS, LI, LU

Table 3.31: Coverage - Data Availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	AT, CY, DE, EE, EL, FI, HR, IE, IT, LV, NO, PT, SK, UK
Confidentiality level 1	SE
Confidentiality level 2	BE, BG, CZ, ES, FR, HU, LT, MT, NL, PL, RO, SI

Table 3.32: Coverage - Data Confidentiality [Source: Axon Consulting]

[25] GSMA's mobile connectivity index for year 2016: https://www.mobileconnectivityindex.com/#year=2016

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to NRAs.

3.1.4.2. Input validation and treatment

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

- *Consistency with GSMA's indicators:* The population coverage per technology provided by each NRA for the year 2016 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 no values had to be adjusted as a result of this review.

- *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.

  Therefore, 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). When population coverage was reported to decrease, it was further investigated and clarified with NRAs. No values had to be adjusted as a result of this review.

- *Technology coverage consistency:* As 2G was the first technology to be deployed, it has typically enjoyed better coverage levels than 3G. The same can be said on the comparison between 3G and 4G. As a result, 2G coverage could be expected to be higher than 3G, and 3G coverage higher than 4G[26].

  The inconsistencies observed were clarified with the NRAs. No values had to be adjusted as a result of this review.

[26] Even if this may not always be the case for all technologies (especially for 4G and 3G), it is the typical trend. Therefore, this analysis helped us to crosscheck a few cases to ensure that they are aligned with the reality in the country.

3.1.4.3. Input definition

As it may be inferred from the outcomes of the previous paragraphs, historical coverage information was provided by all NRAs[27] and it was deemed reasonable and robust after the inputs validation process was performed.

Nevertheless, as indicated at the beginning of this section, coverage has to be 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 2025. 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. At the same time, a common forecasting methodology was used across countries.

Therefore, coverage projections have been defined manually for each country, ensuring consistency between historical data and the typical evolution of mobile networks. The final values defined can be reviewed 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.

[27] With the exception of IS, LI and LU, who did not report any information in the process

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 3.1.6.3.

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[28]*:* The spectrum allocation information available on this website was used as a sanity check to verify the values provided by NRAs.
- EFIS Database[29]: 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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[28] Spectrum monitoring website collects detailed spectrum allocation data of mobile operators- https://spectrummonitoring.com/

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

Data availability:

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

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

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	AT, BE, CY, CZ, DE, EE, EL, FI, IE, NO, PT, RO, SE
Confidentiality level 1	BG, CZ
Confidentiality level 2	BG, ES, FR, HU, IT, LV, MT, NL, PL, SI, SK, UK

Table 3.34: Spectrum - Data Confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to NRAs.

3.1.5.2. Input validation and treatment

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

- 700 MHz
- 800 MHz
- 900 MHz
- 1800 MHz – FDD
- 1800 MHz – TDD
- 2100 MHz – FDD
- 2100 MHz – TDD
- 2600 MHz – FDD
- 2600 MHz – TDD

The information provided for the year 2017 was crosschecked with the alternative sources of information described in the introduction to this section. No relevant differences were spotted and, therefore, the data reported by NRAs was accepted as such.

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 2017:

Band (FDD)	Spectrum (uplink + downlink) for 2017	
	Reference operator with a Market share of 33% (countries with 3 MNOs)	Reference operator with a Market share of 25% (countries with 4 MNOs)
800 MHz	20 MHz	10 MHz
900 MHz	20 MHz	17.4 MHz
1800 MHz	50 MHz	30 MHz
2100 MHz	30-40 MHz*	30 MHz
2600 MHz	40-50 MHz*	30 MHz

Table 3.35: Spectrum – Input definition - Reference spectrum[30] per band for 2017 [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 and 4G 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 following spectrum bands have been disregarded:

- *700 MHz – FDD*: Given that the 700 MHz band is expected to be used to provide 5G services and that this technology has not been modelled, spectrum holdings in the 700 MHz band have not been included in the model.
- *TDD bands (1800 MHz, 2100 MHZ, 2600 MHz)*: Given that a limited number of countries provided information on TDD bands and that this option is not yet massively adopted in the EEA countries, TDD bands have not been considered in the model. It is to be noted as well that virtually no models developed by EEA NRAs model TDD bands.

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, all the spectrum bands presented in Table 3.35 were available from 2015, there are some countries in which this situation does not hold true.

[30] Includes uplink+downlink

In particular, the table below shows the countries in which the 800 MHz and the 2600 MHz were awarded beyond 2015 or are still to be awarded:

Availability year	800 MHz	2600 MHz
2016	CY	CY, PL
2017		
2018	BG, MT	BG, MT
2019		HR
2020		
2021		IE

Table 3.36: Spectrum – Input definition - Availability year for the 800 and 2600 MHz bands [Source: Axon Consulting]

As presented in this table, the 800 MHz and 2600 MHz bands were not considered to be available in these countries until the year indicated above.

Substep 1.3 Consideration of country-specific differentials

Finally, as it was noted in Table 3.35, the average spectrum holdings for a reference operator with 33% market share (countries with 3 MNOs) in the 2100 and 2600 MHz bands is not homogeneous across countries and it may vary slightly among them.

Accordingly, based on the data reported by countries with 3 MNOs, their spectrum holdings in the 2100 and 2600 MHz bands have been 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	30 MHz	40 MHz	50 MHz
2100 MHz	BE, CY, EL, HR, HU, NO	AT, CZ, DE, EE, FI, IE, LT, LV, MT, PT	
2600 MHz		BE, CY, EE, HR, IE, LT, LV, PT	AT, CZ, DE, EL, FI, HU, MT, NO

Table 3.37: Spectrum – Input definition – Spectrum holdings in the 2100 and 2600 MHz considered for the countries with 3 MNOs [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. As the table below shows, while in some cases this situation is clear (e.g. 800 MHz band), further analyses were required for other spectrum bands (e.g. 900 MHz):

Band	Access technologies in which band can be used
800 MHz	4G
900 MHz	2G, 3G and 4G
1800 MHz	2G and 4G
2100 MHz	3G and 4G
2600 MHz	4G

Table 3.38: Spectrum – Input definition - Technologies in which each spectrum band can be used [Source: Axon Consulting]

The following considerations were made for the 900, 1800 and 2100 MHz bands based on the common trends identified from the information reported by NRAs:

- **900 MHz band:** It was considered to be split between 2G and 3G (not 4G), due to its convenient coverage characteristics (which are already fulfilled with the 800 MHz band in the case of 4G). The split considers that 10 MHz (uplink + downlink) is allocated to 3G while the remainder is used in 2G networks.
- **1800 MHz band:** It was split between 2G and 4G. The split considers that 10 MHz (uplink + downlink) is dedicated to 2G while the remainder is used in 4G networks.
- **2100 MHz band:** This band was allocated to 3G networks only, as it was considered that enough 'capacity-driven' spectrum was allocated to 4G while a need for this spectrum was identified for 3G networks.

In addition to this the, following adjustment was performed:

Country	Bands	Issues identified	Adopted approach
CZ	900 and 1800 MHz	As indicated during the 1st consultation, Spectrum in the 900 MHz band can't be used for 3G given the high level of fragmentation. Therefore, in practice, the 900 MHz band is only used for 2G	We have considered that 900 MHz spectrum is only used for 2G. On the other hand, and as per the feedback received, this means that the 1800 MHz band does not need to be allocated to 2G and is therefore fully utilised for the provision of 4G services.

Table 3.39: Spectrum – Input definition – Additional adjustments performed [Source: Axon Consulting]

3.1.6. Unitary Costs

The unitary costs for the assets are defined in the model for the reference year 2017. 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 have been set at country level, provided the information was available and it was robust. 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[31]. 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 2016 and 2017 were obtained primarily from OECD[32] and, if not available from OECD, extracted from World Bank[33].
- Consumer Price Index (CPI) information from IMF[34]: 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 to complement any 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[35].

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	BE, BG, CY, CZ, DE, DK, EL, ES, FI, FR, HR, HU, IE, LT, LV, MT, NL, NO, PL, PT, RO, SE, SI, SK, UK
No information	AT, EE, IT, IS, LI, LU

Table 3.40: Unitary Costs - Data availability [Source: Axon Consulting]

[31] Euro/ECU exchange rates - annual data: http://ec.europa.eu/eurostat/web/products-datasets/-/ert_bil_eur_a
[32] PPP exchange rates from OECD - https://www.oecd-ilibrary.org/economics/data/aggregate-national-accounts/ppps-and-exchange-rates_data-00004-en
[33] PPP exchange rates from World bank - https://data.worldbank.org/indicator/PA.NUS.PPP?end=2017&start=2016&view=bar&year_high_desc=true
[34] International Monetary fund CPI data: http://www.imf.org/external/datamapper/PCPIPCH@WEO/OEMDC/
[35] See reference report for Austria: http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=7720

Data confidentiality:

Confidentiality level	Input
Confidentiality level 0	CY, LT, LV, SE
Confidentiality level 1	NO
Confidentiality level 2	BE, BG, CZ, DK, EL, ES, FI, HR, HU, IE, MT, NL, PL, PT, RO, SI, SK, UK

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

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to NRAs.

3.1.6.2. Input validation and treatment

A thorough exercise has been 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 are 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 2017 PPP of the country referenced to the EU28 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 has been 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
BE, CZ, HR	▶ CapEx	Values reported did not reconcile (difference higher than 35%) with the equivalent GBV from sites registered in the FAR.	Values provided were discarded. An EEA average was used instead.
DK, HR	▶ OpEx	Values reported did not reconcile (difference higher than 35%) with the relevant cost categories from the P&L accounts.	Values provided were discarded. An EEA average was used instead

Table 3.42: 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.
  - Consistency of the costs provided for the different Single RAN configurations. Whenever the unit costs provided for configurations with more technologies/bands were lower than configurations with less technologies/bands, these 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
CY	▶ CapEx	Configurations with 1 band of 2G, 1 band of 3G and 1, 2 or 3 bands of 4G were reported to have higher values than the same configurations but with 2 bands of 2G or 2 bands of 3G	The aforementioned configurations (3) were discarded. The final input considered was calculated from the 33 configurations remaining that were validated in this country, following the approach described in the input definition section.
DK	▶ CapEx	The configuration with 0 bands of 2G, 1 band of 3G and 1 band of 4G was reported to have higher costs than the same configuration but with 1 band of 2G. In addition, the configuration with 1 band of 2G, 2 bands of 3G and 3 bands of 4G was reported to have lower cost than the same configuration but with 2 bands of 4G	The aforementioned configurations (2) were discarded. The final input considered was calculated from the 9 configurations remaining that were validated in this country, following the approach described in the input definition section.
FI	▶ CapEx	The configuration with 2 bands of 2G and 1, 2 or 3 bands of 4G were reported to have the same costs. In addition, the said configurations had lower cost than its equivalents without 2G or with only 1 band of 2G.	The aforementioned configurations (3) were discarded. The final input considered was calculated from the 32 configurations remaining that were validated in this country, following the approach described in the input definition section.

Country	Input	Issues identified	Adopted Approach
HU	▶ CapEx	Values corresponding to the configurations with 2 3G bands were reported by less operators than the rest and showed significantly different costs than the other configurations reported	The aforementioned configurations (8) were discarded. The final input considered was calculated from the 27 configurations remaining that were validated in this country, following the approach described in the input definition section.
MT	▶ CapEx	The configurations with 1 band of 3G and 1, 2 or 3 bands of 4G, as well as the configuration with 2 bands of 3G and 2 bands of 4G were reported to have lower costs than equivalent configurations without 3G.	The aforementioned configurations (4) were discarded. The final input considered was calculated from the 9 configurations remaining that were validated in this country, following the approach described in the input definition section.
NL	▶ CapEx	The configurations with 2 bands of 3G and 1, 2 or 3 bands of 4G, the configurations with 1 band of 2G and 1, 2 or 3 bands of 4G and the configurations with 1 or 2 bands of 3G and 3 bands of 4G were reported to have lower costs than the same configurations but with 2 bands of 2G.	The aforementioned configurations (8) were discarded. The final input considered was calculated from the 26 configurations remaining that were validated in this country, following the approach described in the input definition section.
NO	▶ CapEx	The configuration with 1 band of 3G only was reported to have higher costs than the same configurations but with 1 or 2 bands of 2G	The aforementioned configuration was discarded. The final input considered was calculated from the 2 configurations remaining that were validated in this country, following the approach described in the input definition section.

Country	Input	Issues identified	Adopted Approach
UK	▶ CapEx	16 different configurations were reported to have the same value, which was also lower than any other configuration reported. In addition, the cost of the configurations with no bands of 2G and 3G did not follow a reasonable trend.	The aforementioned configurations (17) were discarded. The final input considered was calculated from the 9 configurations remaining that were validated in this country, following the approach described in the input definition section.
BE, CZ	▶ CapEx	The costs of the configurations reported were significantly above the EEA average. In addition, the values reported did not reconcile with the figures reflected in the FAR.	The values provided were discarded and an EEA average have been used instead.
PL	▶ CapEx	The values reported did not reconcile with the figures reflected in the FAR	The values provided were discarded and an EEA average have been used instead.
IE, NL, SE, SI, UK	▶ OpEx	Same value was reported for all three configurations.	Values were maintained. The methodology followed in this case is presented in the input definition section.
NO	▶ OpEx	The value reported for the configuration with 3 technologies did not correspond to the requested data, as per the NRA's comment.	The value reported was discarded. The input definition calculation was based on the other values reported (2).
BE, HR	▶ OpEx	The values reported did not reconcile with the figures reflected in the relevant P&L accounts.	The values provided were discarded and an EEA average have been used instead.

Table 3.43: 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. When relevant differences were identified, these were further assessed by reviewing the official auction results documents published by NRAs. If relevant discrepancies were identified between both sources that were not justified by NRAs, the information from their official documents was considered.

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

Country	Input	Issues identified	Adopted Approach
BG	▶ Capex 900 MHz, 1800 MHz, 2100 MHz TDD	The unit prices reported by the NRA were not aligned (more than 100% difference) with public references about spectrum auctions in BG.	The price per MHz for the 1800 MHz band was extracted from http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=8146. The price per MHz for the 900 and 2100 MHZ bands was obtained based on the ratio between the cost of these bands and the 1800 MHz band originally reported by the NRA.
DE	▶ Capex 900 MHz, 1800 MHz, 2100 MHz FDD	The unit prices reported by the NRA were not aligned (from 20% to more than 100% difference) with public references about spectrum auctions in DE.	Prices per MHz for the 2100 MHz band were extracted from http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=8153. Prices per MHz for the 900 and 1800 MHz bands were extracted from https://www.bundesnetzagentur.de/EN/Areas/Telecommunications/Companies/FrequencyManagement/ElectronicCommunicationsServices/MobileBroadbandProject2016/project2016_node.html
ES	▶ Capex 800 MHz, 900 MHz, 2600 MHz FDD	Some ad-hoc costs were indicated in the comments section.	These ad-hoc costs were integrated with the spectrum costs reported.

Country	Input	Issues identified	Adopted Approach
FR	▶ Capex 800 MHz and 2600 MHz FDD	The unit prices reported by the NRA were not aligned (more than 100% difference) with public references about spectrum auctions in FR.	Prices per MHz for the 800 and 2600 MHz bands were extracted from http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=8152
IE	▶ Capex 800 MHz, 900 MHz,1800 MHz	Only a portion of the costs was reported by the NRA.	Actual figures from the auction were employed, extracted from http://www.comreg.ie/_fileupload/publications/ComReg12131.pdf

Table 3.44: 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.

In addition to this, the model includes a module to define specific costs on a per-country basis in the case that during the consultation rounds particular unitary costs are evidenced to be different in a given country.

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 have 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 have 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

As outlined by some stakeholders in the first consultation round, the cost of the access sites may vary from country to country given their different macroeconomic conditions. Therefore, the unit cost of these assets has been 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	BG, CY, DE, DK, EL, ES, FI, FR, HR, HU, IE, LT, MT, NL, NO, PL, PT, RO, SE, SI, SK, UK.	BG, CZ, EL, ES, FI, FR, HR, HU, IE, LT, MT, NL, NO, PL, PT, RO, SE, SI, SK, UK.
EEA average used	AT, BE, CZ, EE, HR, IT, LV	AT, BE, CY, DE, DK, EE, HR, IT, LV

Table 3.45: 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 and 1 band in 3G) 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 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:

$$Cost\ of\ configuration = Cost\ per\ Cabinet + \#\,2G\ bands \times Cost\ per\ 2G\ band + \#\,3G\ bands \times Cost\ per\ 3G\ band + \#\,4G\ bands \times Cost\ per\ 4G\ band$$

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 ≥4 configurations were reported*: In this case, we had at least four equations to determine the value of 4 variables, so the system could easily be solved as a mathematical problem.
- *When <4 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 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
Full country-specific costs	BG, CY, ES, FI, HU, PT, RO, SI, SK, PL[36]
Country-specific costs through an adjustment of the EEA averages	DK, EL, HR, IE, LT, LV, MT, NL, NO, SE, UK
EEA averages	AT BE, CZ, DE, EE, FR, IT

Table 3.46: 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 or 3). 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

[36] Values for PL have been extracted from information based on the FAR reported.

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. On the other hand, when inconsistencies were detected in the data reported by some countries (e.g. same OpEx regardless of the number of technologies installed), we have only applied this procedure to determine the fixed component, while the cost per band has been extracted as an EEA average.

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

Approach adopted	Countries
Country-based costs per platform and band	CY, CZ[37], DK, EL, ES, FI, HU, MT, NO, PT, RO, SK
Country-based costs per platform and EEA-averages for the cost per band	IE, LT, LV, NL, SE, SI, UK
EEA Average costs per platform and band	AT, BE, BG, DE, EE, FR, HR, IT, PL,

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

Question 7: Do you agree with the validation, treatment and definition of the unit cost inputs defined for access sites and Single RAN equipment? Otherwise please describe your rationale in detail and provide supporting information and references.

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:

[37] Values have been extracted based on data from their P&L accounts

- 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.

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), have been 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 have 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.

- Extracted from Axon's database: Which is populated from public information published by NRAs. This source was used in the case where no information was provided. In these cases, and when information on the prices paid by MNOs was directly available in our database, this was used to define the spectrum costs' input. Note that the adoption of this approach did not imply any kind of adjustment to the actual prices, given that our database is populated with official information from public references (e.g. NRA, EC).
- Estimation based on EEA average, for those countries where no other information was available, an EEA average was used. This alternative was only used in the cases where no information was provided and where the Axon database did not have data for a particular country or band. 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	Extracted from Axon's database	Estimation based on EEA average
800 MHz	BE, DE, DK, EL, ES, FI, HR, HU, MT, NL, PL, PT, RO, UK	AT, CZ, IE, NO, SK	FR, IT, SE	BG, CY, EE, LT, LV, SI

Bands for which costs were estimated	Data from NRAs	Distribution of bundled costs	Extracted from Axon's database	Estimation based on EEA average
900 MHz	BE, DK, EL, ES, FR, HR, HU, MT, NL, PL, PT, RO, UK	AT, IE, NO	BG, DE	CY, CZ, EE, FI, IT, LT, LV, SE, SI, SK
1800 MHz	BE, DK, EL, ES, FR, HR, HU, MT, NL, PL, PT, RO, UK	AT, CZ, IE, NO, SK	BG, DE, IT, SE	CY, EE, FI, LT, LV, SI
2100 MHz FDD	AT, BE, DK, EL, ES, FR, HR, HU, IE, NL, PL, PT, RO, UK	MT	BG, DE	CY, CZ, EE, FI, IT, LT, LV, NO, SE, SI, SK
2600 MHz FDD	BE, DE, DK, EL, ES, FI, HU, MT, NL, NO, PL, PT, RO, UK	AT, CZ, SK	FR, IT, SE	BG, CY, EE, HR, IE, LT, LV, SI

Table 3.48: Unitary Costs - Input Definition – CapEx Spectrum costs [Source: Axon Consulting].
Note: Even when a band had not yet been auctioned in a country, its costs had to be estimated by Axon to ensure the completeness of the information.

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 KSA. Moreover, most of the trends reported by NRAs showed similarities across the different countries.

In few cases alternative methodologies were used, in particular:

Resource category	Approach adopted
Access Sites	As described in the previous subsection about Unit CapEx and OpEx, no differentiation has been considered among site costs for each geotype. Consistently, a unique cost trend has been applied to access sites, based on the average of information received.
VoLTE	Due to the limited amount of data, VoLTE trends information was discarded. Instead, we relied on the trends corresponding to hardware and software core elements to define the trends for VoLTE.

Resource category	Approach adopted
Spectrum costs	Unit cost was considered to be flat throughout the period under analysis, in line with the approach presented earlier in this section.

Table 3.49: Unitary Costs - Input definition – Unit CapEx prices [Source: Axon Consulting]

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[38]. This source includes actual and projected information for the 2015-2023 period. For 2024 and 2025, the inflation rate was considered to be equal to 2023.

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

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

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	CY, LT, LU
Confidentiality level 1	
Confidentiality level 2	BE, BG, CY, CZ, DK, EL, ES, FR, FI, HR, HU, IE, IT, MT, NO, NL, LT, LV, PT, RO, SI, SK, UK

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

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to 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 3:* 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 0.22% and 1.57%, with most of the references falling around 0.75%. 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.

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). 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 has been 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	FR, HU, UK
High-priority information provided	AT, CY, CZ, DE, EL, ES, HR, IE, LT, LV, MT, NL, NO, RO, SI, SK
Not all High-priority information provided	BE, BG, DK, PL, PT, SE
No information	EE, FI, IS, IT, LI, LU

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

Data confidentiality[39]:

Confidentiality level	Countries
Confidentiality level 0	AT, CY, DE, IE, LT, LV, NL, NO, SE, SK, UK
Confidentiality level 1	

[39] 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, ES, FR, HR, HU, MT, PL, PT, RO, SI

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

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to 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 or 4G 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	▶ SMS traffic distribution per technology	Percentages added up to 50% in 2015 and 2016, instead of 100%.	The traffic on each of the technologies was multiplied by 2, so that the total traffic added up to 100%.
	▶ Voice and data traffic distribution per technology	Percentages for one or more years in either of the two services added up to a figure between 95-105%.	The split was adjusted proportionally to match 100%.
BE, DE, DK, EL, PT, RO, SK	▶ SMS, Voice and Data 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%.

Country	Input	Issues identified	Adopted approach
CY, LT, LV	▶ SMS, Voice and Data traffic distribution per technology	The sum of the percentages of traffic per technology was below 95% or above 105%.	Values discarded for all the services.

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 networks is expected to decrease, while the opposite holds true for 4G networks. Mixed trends are registered with regards to the traffic in 3G networks depending on multiple country-specific factors.

Consistently, the figures provided were reviewed to verify that the percentage of 2G traffic showed a declining pattern, while the percentage of 4G traffic showed an uptrend. The cases in which this was not the case are described below, together with the approach adopted, which is differentiated as per whether it applies to one or both of the scenarios defined:

Country	Input	Scenario	Issues identified	Adopted Approach
DE	▶ Data LTE 2018 and 2019.	Both	The percentage of data traffic over LTE was reported to have a minimal decrease between 2017 and 2019, while it showed a relevant increase in 2020.	A linear trend was drawn between the percentage of data traffic over LTE in 2017 and 2020 to soften the trend reported by the NRA. The percentage of traffic in 3G was adjusted to ensure that the sum of 2G, 3G and 4G traffic did still add up to 100%.

Country	Input	Scenario	Issues identified	Adopted Approach
BG	▶ Voice Traffic split for 2019 - 2021	Projections based on historical trends	The operators reporting data for the 2019 – 2021 period differed from those reporting data for the 2015 -2018. This caused inconsistencies in the YoY evolution of the disaggregation.	Information discarded for the years 2019 to 2021. Values for these years were estimated as described in the input definition section.
FR	▶ Data traffic split from 2018-2025	Projections based on historical trends	Data traffic distribution was reported to remain constant from 2021 to 2025 and LTE data traffic showed an unrealistic trend in the 2018-2021 period.	Data traffic split has been extrapolated based on historical trends.
	▶ Voice traffic split from 2021-2025	Projections based on historical trends	Voice traffic distribution was reported to remain constant from 2021 to 2025.	Voice traffic split has been extrapolated based on historical trends.
	▶ SMS traffic split from 2017-2025	Projections based on historical trends	SMS traffic distribution was reported to remain constant from 2017 to 2025.	SMS traffic split has been extrapolated based on historical trends
SI	▶ SMS traffic 2018	Projections based on historical trends	The traffic disaggregation in 2018 showed a sudden change when compared with the trend registered in previous years (sudden increase of 2G and decrease of LTE).	GSM and UMTS traffic percentages were extrapolated based on the 2016 to 2017 growth rates. LTE traffic percentage was estimated as the remaining percentage until 100%.

Country	Input	Scenario	Issues identified	Adopted Approach
SK	▶ Voice traffic 2019 - 2021	Projections based on historical trends	GSM Voice traffic distribution from 2019-2021 was reported to be constant.	GSM Voice traffic percentage from 2019-2025 has been extrapolated based on the 2017-2018 growth rate. All traffic percentages per year were then adjusted so that they added up to 100%.
	▶ SMS traffic (2015-2021)	Projections based on historical trends	LTE traffic was set to zero throughout the whole period reported	Data was discarded. In this case, the same values used in the "Same percentage across EEA from 2020" scenario have been considered.
RO	▶ Data GSM in 2018	Projections based on historical trends	The percentage of data traffic over 2G increased in 2018, contrary to expectations, to resume the decrease in 2019 towards lower values than in 2017.	The percentage of 2G data traffic in 2018 was calculated as the average of the 2017 and 2019 references to ensure a reasonable trend across the period. The percentage of 4G data traffic in 2018 was adjusted to ensure the sum of the percentages of 2G, 3G and 4G traffic added 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 separately for traffic-related services (e.g. voice, SMS, data) and for subscribers. Given that the approach adopted in both cases differed, the methodology adopted for traffic and subscribers is presented in two different sections below.

Traffic distribution

The definition of the traffic disaggregation by technology was based on the information provided by stakeholders that was validated in the previous step.

Similarly to the approach adopted for demand, this section is split below between the definition of historical traffic distribution (including near term projections) and long term projections for traffic distribution. Note that for long-term projections, the approach adopted to define the inputs under the two scenarios considered is presented in two different sections.

Historical and near-term projections (until 2019)

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. When NRAs did not submit information about VoLTE usage (or it was reported to be 0%), the percentage of VoLTE traffic was defined through a linear trendline between 2017 (assumed to be the first year in which VoLTE should be in place) and the percentage of VoLTE traffic assumed for 2020 (see further indications on this in the upcoming paragraphs about long term projections). The percentages of voice traffic in 2G and 3G technologies were adjusted proportionally between the 2017-2019 period.

In some circumstances when any specific data points were missing between existing data, a linear extrapolation was made.

Lastly, when a country did not provide information about traffic distribution per technology, an EEA average was used.

Long-term projections (from 2020) - "Same percentage across EEA from 2020" scenario

The information collected with regards to long-term projections was limited. Therefore, a detailed methodology had to be defined in order to determine the inputs to be considered for the period from 2020 to 2025.

The paragraphs below describe the approach adopted to calculate the voice, SMS and data long-term projections:

- **Voice projections:** Voice projections were calculated with the objective that the VoLTE projections reflected a reasonable take-up of VoLTE-ready handsets in the EEA. Particularly, the steps performed to calculate the voice projections are described below:
  1. Calculation of the yearly average take-up of VoLTE-ready handsets in the EEA, based on the information collected from the reporting countries.
  2. Calculation of the average distribution of voice traffic per technology in the EEA. This value is used in order to avoid skewing the voice distribution towards those countries with a higher VoLTE adoption.
  3. The outcomes of Steps 1 and 2 were considered in the definition of the of the voice traffic that will be handled through 4G networks.
  4. The 3G voice traffic percentage was calculated as the yearly EEA average for the 2020-2025 period.
  5. The 2G voice traffic percentage was calculated as 100% minus the percentages of 3G and 4G voice traffic.
- **Data projections:** Data projections were based on the values reported by NRAs for the 2020-2025 period following the steps described below:
  1. The 2G data traffic percentage was calculated as the yearly EEA average for the 2020-2025 period.
  2. The 3G data traffic percentage was calculated as the yearly EEA average for the 2020-2021 period. The declining pattern in the 3G data percentage calculated between 2020 and 2021 was projected to the 2022-2025 period.
  3. The 4G data traffic percentage was calculated as 100% minus the percentages of 2G and 3G data traffic.

- **SMS traffic split for the 2020-2025 period:** Given the scarcity of information with regards to the SMS traffic distribution, the same percentages considered for voice were also adopted for SMSs.
- **Subscribers:** Similar to data, voice, and SMS traffic, we had to define a split of subscribers per access technology. This input represents the percentage of subscribers that have access to the most-recent access technology (e.g. a 2G subscriber represents a user that does not use 3G or 4G, while a 4G subscriber represents a user that may make use of 2G and 3G networks). The split per technology was performed as follows:

  1. The percentage of 4G subscribers was calculated as the ratio between 4G subscribers and total subscribers provided by NRAs. When this information was not reported, an EEA average was used.
  2. The percentage of 2G subscribers was taken from CNMC's Bottom-Up model, as it was the only reference identified that included this split. It is noteworthy that the impact of this percentage in the model is virtually null.
  3. Finally, the percentage of 3G subscribers was calculated as 100% minus the percentage of 2G and 4G subscribers.

  The forecast of the subscribers' distribution per technology was performed as follows:

  1. The 4G percentage was projected by means of a logarithmic-shaped extrapolation of historical trends, assuming that the percentage of 4G subscribers towards 2025 will get close to 90%.
  2. Equivalently to the approach adopted with regards to the historical data, the 2G subscribers' projection was also extracted from CNMC's Bottom-Up model.
  3. Finally, the percentage of 3G subscribers was calculated as 100% minus the percentage of 2G and 4G subscribers.

Long-term projections (from 2020) - "Country specific projections" scenario

The projections performed under this scenario are based on the validated country-level data in terms of historical and forecast traffic 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 under this scenario.

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 (2015-2017) 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.

  For instance, a particular country (A) may have initiated the deployment of VoLTE networks in 2016 while a second country (B) may have begun in 2017. At the same time, the VoLTE traffic adoption in country B in year n, was similar to that in country A for year n-1. Therefore, the same growth rates registered in country A in the year n-1 could be considered in country B in the year n, as the exhibit below shows:

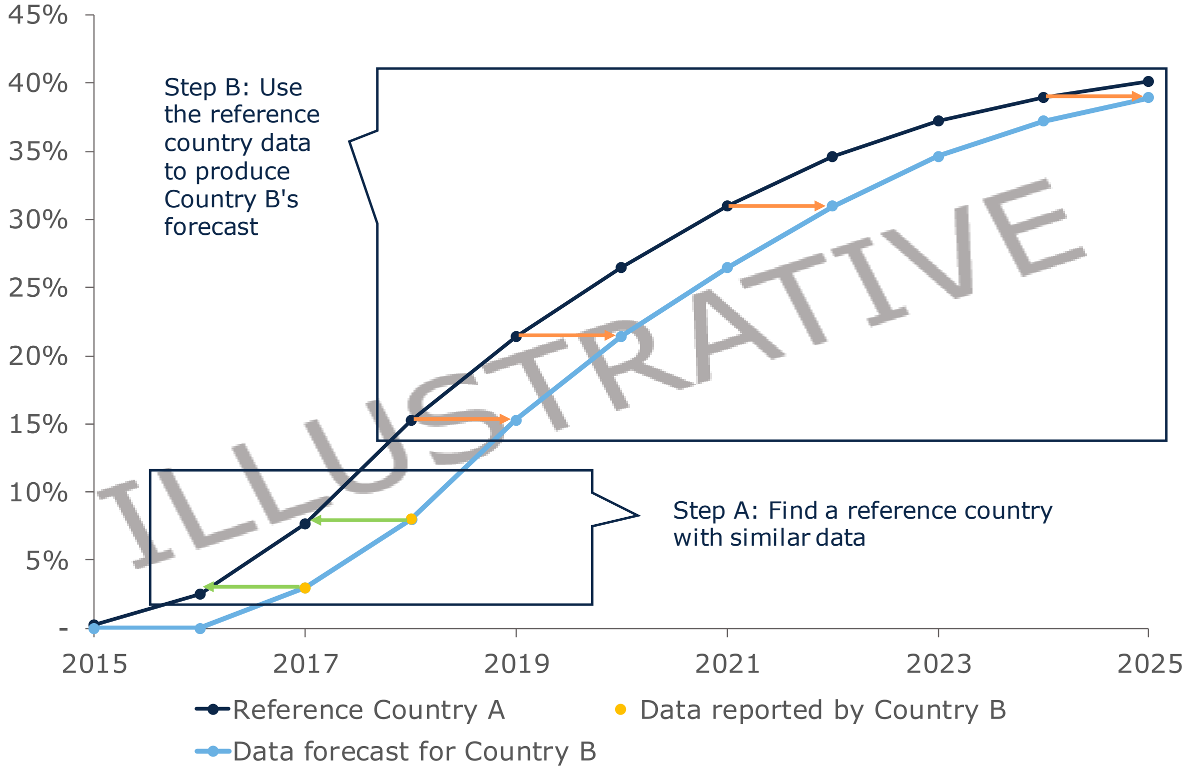


Table 3.56: Traffic distribution per technology – Input definition – Procedure to project the traffic split per technology forecast when no data was available [Source: Axon Consulting]

Question 8: Do you agree with the validation, treatment and definition of the traffic distribution per technology inputs defined for the "Country specific projections" scenario? Otherwise please describe your rationale in detail and provide supporting information and references.

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. Information is introduced as a blended ARPU without any service split given that not enough information was provided by NRAs.

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[40] 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	
High-priority information provided	BE, BG, CY, CZ, EL, ES, FI, HU, IE, LV, MT, NL, NO, PL, SE, SI, SK
Not all High-priority information provided	AT, DE, DK, FR, HR, IT, LT, PT, RO, UK
No information	EE, IS, LI, LU

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

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	AT, CY, DE, FI, IE, LV, NO, SE, SK
Confidentiality level 1	HR, MT,

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

Confidentiality level	Countries
Confidentiality level 2	BE, BG, CZ, DK, EL, ES, FR, HU, LT, NL, PL, PT, RO, SI, UK

Table 3.58: ARPU - Data Confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to 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. No issues were identified.

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. In particular, virtually all NRAs reported a notably flat trend throughout the 2015-2025 period.

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 2015[41].

3. The ARPU for the years beyond 2015 was calculated as:

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

[41] 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 2015 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 3.1.16.

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, the high-priority information requested in the Form.

Data availability:

Status	Countries
Complete information	ES, FR, HU, PL
High-priority information provided	DE, EL, HR, IE, MT, NL, SK

Status	Countries
Not all High-priority information provided	CY, CZ, DK, IT, PT
No information	AT, BE, BG, EE, FI, IS, LI, LT, LU, LV, NO, RO, SE, SI, UK

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

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	
Confidentiality level 1	
Confidentiality level 2	ES, HU, PL, EL, FR, HR, NL, SK, CY, CZ, DK, IT, MT, PT

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

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to NRAs.

3.1.10.2. Input validation and treatment

The information provided by NRAs was validated from two 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. No issues were identified.

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

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 April 2017 and April 2018, 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 April 2017 to April 2018).
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%[42] 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

[42] 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.

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:

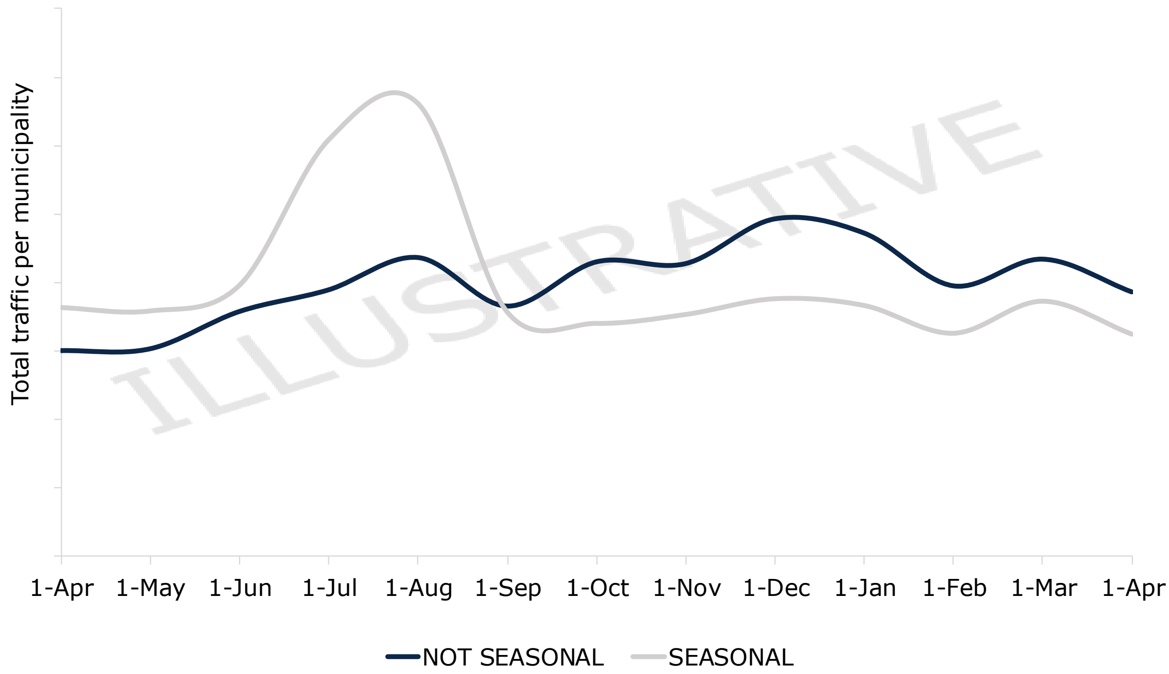


Figure 3.2: Seasonality – Input definition– Illustrative example of seasonality [Source: Axon Consulting]

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-Mar 2017 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 March 2017[43]. This was estimated by extrapolating the April 2017 traffic backwards based on the growth rates registered, at municipality level, between January-March 2018.
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

[43] Please note that the information was requested for the period April 2017 to April 2018 to reduce the amount requested to the stakeholders.

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.

The exhibit below shows the outcomes of this analysis for the 11 countries in which it was possible to assess the existence of seasonality:

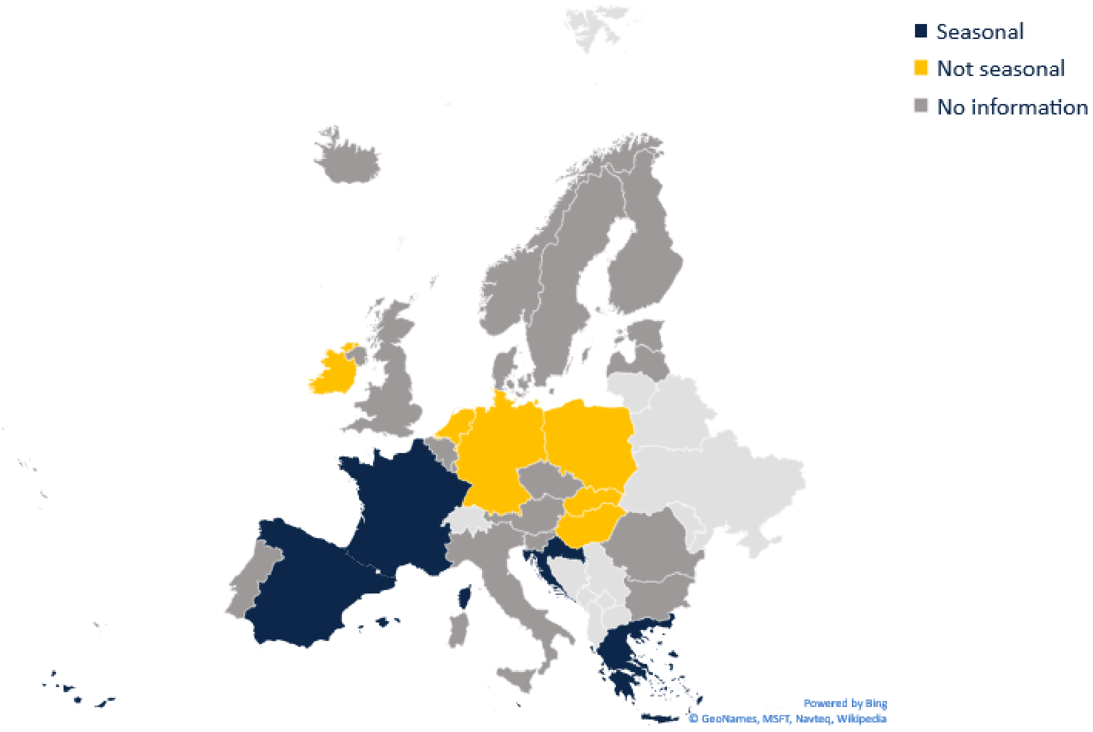


Figure 3.3: Seasonality – Input definition– Seasonality assessment in Europe [Source: Axon Consulting]. Note: Even though not visible in the map, Malta was also classified as seasonal.

A country was considered as seasonal when at least one geotype was disaggregated between seasonal and non-seasonal. The 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 FY2017:* This step was carried out to identify the month with the highest nominal traffic for each municipality for the January 2017-December 2017 period.
2. *Calculation of busiest month traffic per geotype:* The information calculated in step 1 above is 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.

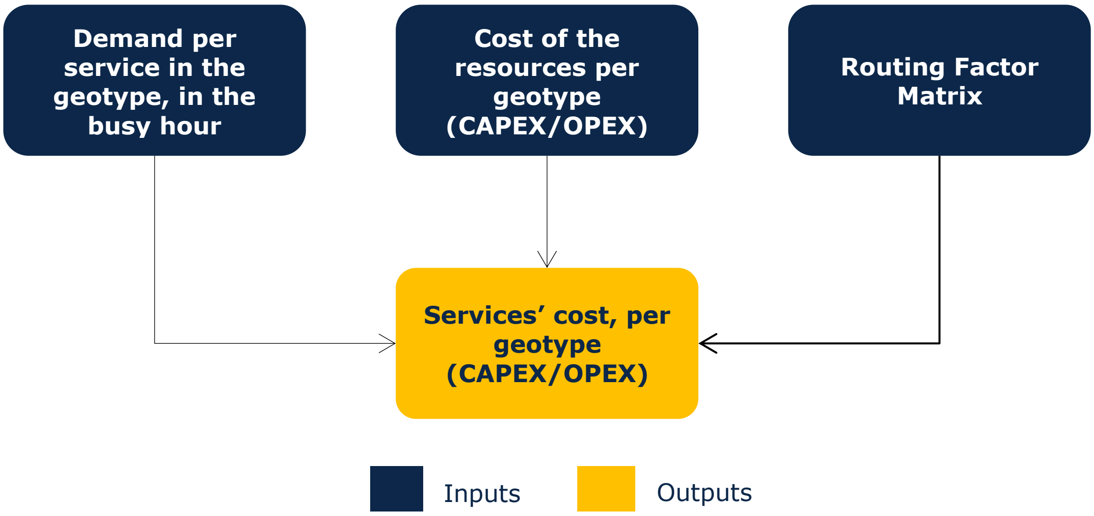


Figure 3.4: Cost allocation process through Routing Factors. [Source: Axon Consulting]

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. Cell Radii

Cell radii are defined in the model per technology, spectrum band and geotype. Two different scenarios have been set in the definition of this input, as explained in section 2.6. Cell radii are used in the model to calculate the number of sites needed to reach the coverage levels defined.

The cell radii inputs are included in worksheet '2C INP CELL RADIUS' of the model.

3.1.11.1. Sources of information

The source of information to define the cell radii was the data provided by the NRAs, as they typically reported the information requested in the Form. The tables below indicate the availability and confidentiality of cell radii data per country reported by NRAs.

Data availability:

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

Table 3.62: Cell radii - Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	CY, DE, NL, SE, SK, UK
Confidentiality level 1	
Confidentiality level 2	BG, CZ, DK, EL, ES, FI, FR, HR, HU, IE, IT, MT, PT, RO, SI

Table 3.63: Cell radii - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to NRAs.

3.1.11.2. Input validation and treatment

All the figures provided by NRAs were within a reasonable and expectable range. Therefore, no values were either discarded or adjusted as part of the data validation process.

3.1.11.3. Input definition

The data requested in the data collection process was disaggregated per spectrum band basis (including an additional split per geotype) while the inputs considered in the cost model are also disaggregated by technology. Therefore, the first step towards the definition of the cell radii inputs consisted in establishing a relationship between both references:

Technology and band considered in the cost model	Relevant reference from the data request
GSM 900	900 MHz
GSM 1800	1800 MHz - FDD
UMTS 900	900 MHz
UMTS 2100	2100 MHz - FDD
LTE LOW	800 MHz
LTE MID	1800 MHz
LTE HIGH	2600 MHz

Table 3.64: Cell radii – Relationship between the model's and the data request's references [Source: Axon Consulting]

As introduced in section 2.6, two different scenarios were built up to set the cell radii inputs, namely:

- Mix EEA Average – Country specific figures scenario
- Country specific figures only scenario

The paragraphs below describe how the cell radii inputs were defined for each of these two scenarios.

Input definition - "Mix EEA Average – Country specific figures" scenario

The main assumption under the construction of this scenario is that, while it is acceptable to recognise that there are differences among countries in the cell radii that can be reached in the radio access network due to geographical, demographic or technical aspects, these factors alone would not explain the severe differences identified in the data reported by stakeholders (see Exhibit 2.6).

Therefore, in order to balance the potential existence of differences among countries while recognising that a common pattern should be recognisable at EEA level, three cell radii datasets (each dataset containing one cell radius for each combination of technology, band and geotype) have been calculated based on the data reported by stakeholders, as follows:

- *Average cell radii dataset*: Based on the average of all cell radii reported by all stakeholders.
- *Low cell radii dataset*: Based on the average of the cell radii of the 50% stakeholders that reported the lowest cell radii values.
- *High cell radii dataset*: Based on the average of the cell radii of the 50% stakeholders that reported the highest cell radii values.

Considering the inputs originally reported by the NRAs, the following datasets have been adopted for each combination of technology, band, geotype and country:

Tech.	Band	Geotype	Low	Average	High
GSM	900	Urban	AT, BE, HU	CY, DK, DE, IT, LV, LT, NL, NO, PT, SK, SI, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, PL, RO
		Suburban	AT, BE, DK, DE, HU	CY, EL, IT, LV, NL, NO, PT, SK, SI, ES, UK	BG, HR, EE, FI, FR, IE, LT, PL, RO, SE
		Rural	AT, HU	CY, DK, DE, IT, LV, NL, PT, SK, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, LT, NO, PL, RO, SI
	1800	Urban	AT, BE, HU	CY, DK, DE, IT, LV, LT, NL, NO, PT, SK, SI, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, PL, RO
		Suburban	AT, BE, DK, DE, HU	CY, EL, IT, LV, NL, NO, PT, SK, SI, ES, UK	BG, HR, EE, FI, FR, IE, LT, PL, RO, SE
		Rural	AT, HU	CY, DK, DE, IT, LV, LT, NL, PT, SK, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, NO, PL, RO, SI

Tech.	Band	Geotype	Low	Average	High
UMTS	900	Urban	AT, BE, HU	CY, DK, DE, IT, LV, NL, NO, PT, SK, SI, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, LT, PL, RO
		Suburban	AT, BE, DK, DE, HU	CY, EL, IT, LV, LT, NL, NO, PT, SK, SI, ES, UK	BG, HR, EE, FI, FR, IE, PL, RO, SE
		Rural	AT, HU	CY, DK, DE, IT, LV, LT, NL, PT, SK, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, NO, PL, RO, SI
	2100	Urban	AT, BE, HU	CY, DK, DE, IT, LV, LT, NL, NO, PT, SK, SI, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, PL, RO
		Suburban	AT, BE, DK, DE, HU	CY, EL, IT, LV, NL, NO, PT, SK, SI, ES, UK	BG, HR, EE, FI, FR, IE, LT, PL, RO, SE
		Rural	AT, HU	CY, DK, DE, IT, LV, NL, PT, SK, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, LT, NO, PL, RO, SI
LTE	LOW	Urban	AT, BE, HU	CY, DK, DE, IT, LV, LT, NL, NO, PT, SK, SI, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, PL, RO
		Suburban	AT, BE, DK, DE, HU	CY, EL, IT, LV, LT, NL, NO, PT, SK, SI, ES, UK	BG, HR, EE, FI, FR, IE, PL, RO, SE
		Rural	AT, HU	CY, DK, DE, IT, LV, LT, NL, PT, SK, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, NO, PL, RO, SI
	MID	Urban	AT, BE, HU	CY, DK, DE, IT, LV, LT, NL, NO, PT, SK, SI, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, PL, RO
		Suburban	AT, BE, DK, DE, HU	CY, EL, IT, LV, LT, NL, NO, PT, SK, SI, ES, UK	BG, HR, EE, FI, FR, IE, PL, RO, SE
		Rural	AT, HU	CY, DK, DE, IT, LV, LT, NL, PT, SK, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, NO, PL, RO, SI
	HIGH	Urban	AT, BE, HU	CY, DK, DE, IT, LV, LT, NL, NO, PT, SK, SI, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, PL, RO
		Suburban	AT, BE, DK, DE, HU	CY, EL, IT, LV, LT, NL, NO, PT, SK, SI, ES, UK	BG, HR, EE, FI, FR, IE, PL, RO, SE
		Rural	AT, HU	CY, DK, DE, IT, LV, LT, NL, PT, SK, ES, SE, UK	BG, HR, EE, FI, FR, EL, IE, NO, PL, RO, SI

Table 3.65: Cell radii – Input definition (mix EEA average – country specific) – Datasets considered per country [Source: Axon Consulting]

Additionally, in some particular circumstances, country-specific cell radii were adopted to ensure a proper representation of the characteristics of that country which, for some different reasons, make them deviate from the EEA average. These cases are listed below:

Country	Technology/Bands/ Geotypes	Approach adopted
CZ	▶ All	Country specific values were used based on the data reported by the NRA. The values provided by the NRA were validated through a geographical analysis where the inter-site distance was observed to be representative of the cell radii values reported by the NRA.
MT	▶ All	Country specific values were used based on the data reported by the NRA. The NRA confirmed that the cell radii reported was based on the actual radii used by MNOs in its country, which are heavily affected by indoor propagation limitations due to the thickness of the walls in Malta, as well as the high population density.
BE	▶ All bands and technologies in rural geotypes	Country specific values were used based on the data reported by the NRA. Based on feedback from the NRA and MNOs in the country, the values reported in the data request process were representative of their realities. Those same figures had been considered in the NRA's own cost model.

Table 3.66: Cell radii – Input definition (mix EEA average – country specific) – Cases in which country specific figures were adopted [Source: Axon Consulting]

Input definition - "Country specific figures only" scenario

This scenario was included into the model to accommodate stakeholders' feedback in the first consultation round. While, under this scenario, the cell radii provided by NRAs were directly included in the model for most countries, the high differences between the values provided by NRAs (see Exhibit 2.6) mean that its results are not always reliable.

Countries that did not report any value were not considered under the definition of inputs in this scenario. This is, in these cases, the same cell radii as in the "Mix EEA Average – Country specific figures" scenario were used.

On the other hand, when values were missing for some combinations of technology, band and geotype, these were calculated based on ratios and other available information, as shown in the table below:

Country	Technology/Bands/Geotypes	Approach adopted
HR, CY, IE, SI, SK	▶ LTE High (all geotypes)	Figures were calculated based on the average ratio between LTE cell radius for high bands and LTE cell radius for mid bands at EEA level, multiplied by the country specific LTE cell radius for mid bands.
DK, HU	▶ LTE Low (all geotypes)	Same figures as for the cell radius for the 900 MHz.
UK	▶ GSM and UMTS 900 (all geotypes)	Same figures as for the LTE cell radius for low bands.

Table 3.67: Cell radii – Input definition (Country specific figures only) – Adjustments to the data provided [Source: Axon Consulting]

Question 9: Do you agree with the validation, treatment and definition of the cell radii inputs under both scenarios defined? If you don't, please justify your position and provide supporting information and references.

3.1.12. 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.

3.1.12.1. 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	BE, CY, CZ, ES, HU, MT, PL, RO, SI
High-priority information provided	FR, NL, PT
Not all High-priority information provided	AT, BG, DE, DK, EL, HR, IE, IT, LV, NO, SE, SK, UK
No information	EE, FI, IS, LI, LU, LT

Table 3.68: Busy hour and traffic in weekdays - Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality levels	Countries
Confidentiality level 0	AT, CY, DE, ES, LV, NL, NO, SK, UK
Confidentiality level 1	

Confidentiality levels	Countries
Confidentiality level 2	BE, BG, CZ, DK, EL, FR, HR, HU, IE, IT, MT, PL, PT, RO, SE, SI

Table 3.69: Busy hour and traffic in weekdays - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to NRAs.

3.1.12.2. 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
CY, CZ	▶ Traffic during weekdays for data traffic	References were more than 10 percentage points below the EEA average	References discarded
CY	▶ Traffic during weekdays for voice traffic	References were more than 10 percentage points below the EEA average	References discarded
SK	▶ Traffic during weekdays for roaming traffic	References were more than 10 percentage points below the EEA average	References discarded

Table 3.70: 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 in BG and CY for the hourly traffic distribution for roaming data and in LV and RO for the hourly traffic distribution for all the services. These references were discarded.

- *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. No issues were identified.

3.1.12.3. 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, CY, EE, FI, IE, LT, LV, UK
Data traffic	AT, CY, CZ, EE, FI, IE LT LV, UK

Table 3.71: 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
Data traffic	Domestic	CY, EE, FI, LT, LV
	Roaming EEA	AT, BG, CY, DK, EE, FI, IE, LT, LV, NO, SE, SI
	Roaming Non-EEA	AT, BG, CY, DK, EE, FI, FR, HR, IE, IT, LT, LV, NO, SE, SI, UK
Voice traffic	Domestic	CY, EE, FI, HR, LT, LV
	Roaming EEA	AT, BG, CY, CZ, DE, DK, EE, FI, HR, IT, LT, LV, NO, SE, UK
	Roaming Non-EEA	AT, BG, CY, CZ, DE, DK, EE, FI, FR, HR, IT, LT, LV, NO, SE, SK, UK

Table 3.72: Busy hour and traffic in weekdays - Input definition – Busy hour traffic percentage [Source: Axon Consulting]

3.1.13. Backbone

While the dimensioning of the backhaul network may be performed under a purely scorched earth perspective, the design of the backbone network needs to be based on the actual networks deployed by MNOs. This is because a theoretical design of a backbone network could be far from the reality of the MNOs' networks.

Consequently, detailed inputs that characterise the backbone network of the reference operator in each EEA country have been produced. These inputs will be used in the model to properly dimension the backbone network.

The backbone inputs are included in worksheet '2F INP BACKBONE & CORE' of the model.

3.1.13.1. Sources of information

The main source of information was the data reported by NRAs through the Data Request Form. This data was complemented when required with geographical information from Google Maps API.

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

Data availability:

Status	Countries
Complete information	BE, BG, CY, CZ, HU, IE, IT, MT, NL, PT, SK, UK
High-priority information provided	AT, DE, DK, EL, ES, FR, HR, LV, LT, PO, RO

Status	Countries
Not all High-priority information provided	
No information	EE, FI, IS, LI, LU, NO, SE

Table 3.73: Backbone - Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality levels	Countries
Confidentiality level 0	AT, DE, IE, LT, UK
Confidentiality level 1	
Confidentiality level 2	BE, BG, CY, CZ, DK, EL, ES, FR, HR, HU, IT, LV, MT, NL, PL, PT, RO, SI, SK

Table 3.74: Backbone - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to NRAs.

3.1.13.2. Input validation and treatment

As part of the review of the data reported by NRAs, it was acknowledged that the definition of core nodes was probably blur and stakeholders interpreted the request in different ways. Apparently, some understood that core nodes should be defined as the locations where they had a controller (e.g. BSC, RNC) while others considered that these should be defined as the locations where they had a main switching platform (e.g. MGW, MSC).

Our definition of the backbone network begins at the controllers' level, and includes the controller to core platforms as well as the core platforms to core platforms links. Therefore, the core locations required from NRAs should have related to controller locations.

In order to identify potential misunderstandings in the definition of the core locations, we cross-checked the reasonability of the ratio between the number of BSCs and RNCs reported by NRAs and the number of core locations indicated. When this ratio was higher than two, it was concluded that the number of core locations provided related to a higher level of the network and, therefore, some controller locations were missed.

In order to properly account for these cases, the process described below was adopted:

- *Step 1: Define the number of core nodes of an efficient operator*: When cases were found in which the core locations provided by NRAs did not seem to correspond to the number of controller locations, the number of controller locations for the reference operator was calculated as the average of the BSCs/RNCs reported by the MNOs in a country (whatever was higher) divided by the average co-located controllers in the EEA reporting countries.
- *Step 2: Define the coordinates of the core nodes locations:* The number of core nodes determined in Step 1 above had to be plotted into specific locations of the country. In order to do so, preference was given to locate core nodes in the major cities of the country which, according to their position, the deployment of a core node could bring advantages to the overall management of the backbone network. This was a predominantly manual exercise, performed on a country level, that aimed at ensuring that the locations selected were logical based on the demographic characteristics of the country.

The same approach described in the paragraphs above was also adopted in when NRAs did not report information on the locations of the core nodes.

3.1.13.3. Input definition

Backbone inputs were defined based on the indicators that are thoroughly described below:

- Core nodes
- Links and distance
- Percentage of traffic per link
- Technology mix

Core nodes

The number of core nodes and their corresponding locations were directly extracted from the validated and treated data as per the instructions given in the previous section.

The exhibit below provides an illustrative overview of the definition of the core locations in a country[44]:

[44] For the sake of preserving confidentiality, all the figures presented in this section do not relate to any country in particular. They all represent a dummy scenario.

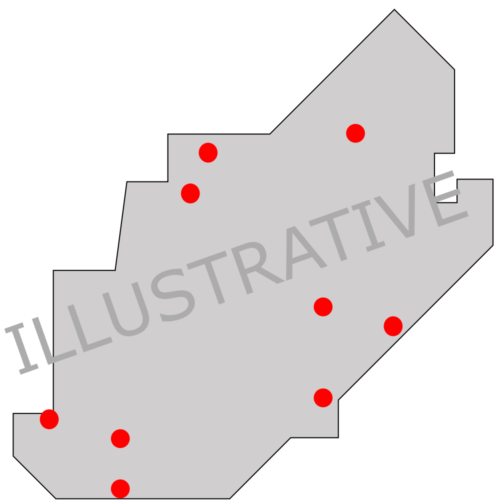


Figure 3.5: Backbone – Input definition – Core nodes [Source: Axon Consulting]

Links and distance

This phase consisted in the design of the complete backbone transmission network and the links between core locations. In order to do so, the following steps were performed:

- Step 1: Definition of core nodes' role
- Step 2: Links' building
- Step 3: Distance measurement
- Step 4: Consolidation of the results

Step 1: Definition of core nodes' role

Depending on the relevance of the core nodes, these were classified as level 1 or level 2. Level 1 nodes represented the core nodes that, as reported by the NRAs, act as major interconnection points in the country. Level 2 nodes represented the remaining cases.

When information was not available on the relevance of the core nodes (e.g. which of them acted as national interconnection points), their levels were manually determined by Axon in order to ensure the reasonability of the resulting backbone network.

The following exhibit shows the classification performed of the core nodes presented before:

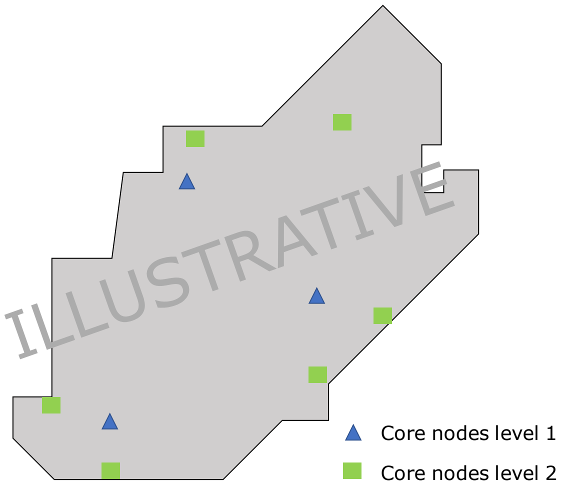


Figure 3.6: Backbone – Input definition – Definition of core nodes' role [Source: Axon Consulting]

Step 2: Links' building

Having identified the location and levels of the core nodes, the following substeps were performed to build up the links between the different locations:

- *Substep 1: Creation of rings around each core node level 1*. A ring-shaped link was defined that interconnected the core nodes level 2 with their nearest core node level 1. Hence, a ring was constituted around each core node level 1 as the exhibit below shows:

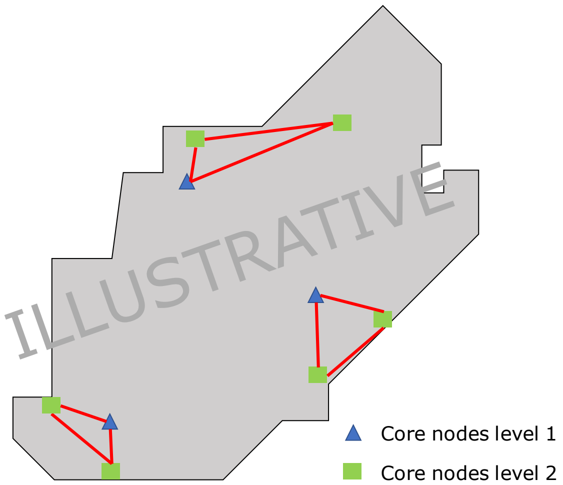


Figure 3.7: Backbone – Input definition – Rings around each core node level 1 [Source: Axon Consulting]

Each of these rings was built up in a way that minimised the overall distance of the ring. This feature was particularly relevant in countries with a high number of core locations.

- *Substep 2. Interconnection of core nodes level 1*: Once the rings around each core node level 1 were set up, each of the core node level 1 locations was interconnected by means of another ring (hereinafter referred to as the 'inter-core ring'). This ring was built up according to the same approach as previously described for the rings constituted in substep 1. The exhibit below provides a graphical representation of the inter-core ring:

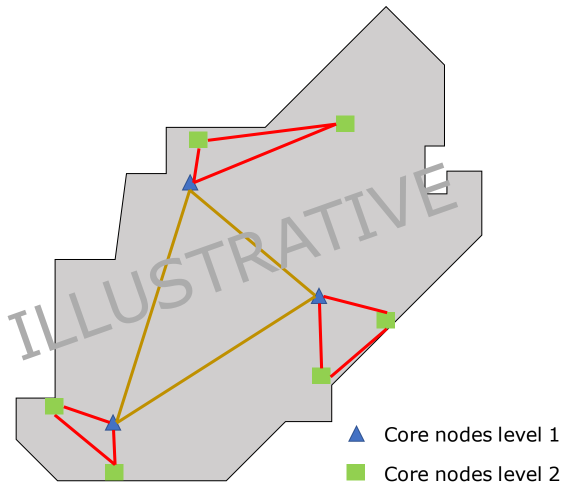


Figure 3.8: Backbone – Input definition – Inter-core ring [Source: Axon Consulting]

Step 3: Distance measurement

Although the links plotted in the previous exhibit show a straight-line between two points, the calculation of the links' distance was performed according to the real road-distance between two given locations. This information was extracted from Google maps API for each link defined.

Step 4: Consolidation of the results

Considering the outcomes of steps 2 and 3 above, this step calculated the overall number of links designed in each country, as well as their average distance (calculated as the total distance measured divided by the number of links defined).

Percentage of traffic per link

The percentage of traffic per link is calculated based on the structure of the backbone network determined in step 2 above. Specifically, the following formula was employed to calculate the percentage of traffic per link:

$$\%\,traffic\ per\ link = \frac{1\ + \#\ links\ in\ the\ InterCoreRing}{Total\ number\ of\ links}$$

Where,

- $\#\,links\ in\ the\ InterCoreRing$ is the number of links calculated in step 2, substep 2 above. In the example presented in the exhibits, this element would be equal to 3.
- $Total\ number\ of\ links$ is the sum of links constituted in step 2. In the example presented in the exhibits, this element would be equal to 12.

The approach adopted considers that all the traffic in the network will go through the inter-core links while each of the secondary links will only be responsible for handling a percentage of the total traffic in the network (equal to 1/# of secondary links).

Technology mix

Finally, considering the information provided by NRAs, it was observed that backbone networks were typically comprised of fibre optic links. While it is true that fibre optic links were complemented by microwave links in some countries, these did never play a major role in the design of the backbone network.

Consequently, and to increase consistency across EEA countries, all backbone networks were designed under an all-fibre approach.

3.1.14. 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.

3.1.14.1. 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	AT, BE, BG, CY, CZ, DE, DK, ES, FI, FR, HR, HU, IE, LT, LV, MT, NL, NO, PL, PT, RO, SE, SI, SK, UK
High-priority information provided	
Not all High-priority information provided	EL, IT
No information	EE, IS, LI, LU

Table 3.75: Useful lives - Data availability [Source: Axon Consulting]

Data confidentiality:

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

Table 3.76: Useful lives - Data Confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to NRAs.

3.1.14.2. 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)	SE
Access towers	CY, EL, IT, MT, NL
Access node hardware	IE, SE
Access node software	CY, IE, LT, NL, SE
Microwave tower	AT, BG, CY, LT, LV, MT, NL, NO, SE, SI, SK
Microwave equipment	IE, SE
Optical fibre cables and civil infrastructure	HU, IE, IT, LV, NL
Optical fibre active equipment	SE
IP switching	SE
Core buildings	BE, CZ, IT, MT, SI
Core equipment hardware	SE
Core equipment software	IE, LT, NL, NO, SE
700 MHz spectrum license	AT, IT, LT
800 MHz spectrum license	IT
900 MHz spectrum license	BE, IT
1800 MHz spectrum license	BE, IT
2100 MHz FDD spectrum license	
2100 MHz TDD spectrum license	LT

Asset category	Outliers
2600 MHz FDD spectrum license	IT
2600 MHz TDD spectrum license	IT, LT

Table 3.77: Useful lives – Data validation [Source: Axon Consulting]

3.1.14.3. 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 have been 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
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

Resource category from the Form	Resource variable from the model
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
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

Resource category from the Form	Resource variable from the model
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
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
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 FDD spectrum license	LIC.Licence 2100 FDD.MHz
2100 MHz FDD spectrum license	LIC.Licence 2600 FDD.MHz
2100 MHz FDD spectrum license	LIC.Licence 1500 TDD.MHz
2100 MHz FDD spectrum license	LIC.Licence 1800 TDD.MHz
2100 MHz TDD spectrum license	LIC.Licence 2100 TDD.MHz
2100 MHz FDD spectrum license	LIC.Licence 2300 TDD.MHz
2600 MHz TDD spectrum license	LIC.Licence 2600 TDD.MHz

Table 3.78: Useful lives –Input definition - Mapping of asset references [Source: Axon Consulting]

In the case of spectrum licenses, we have defined this based on the actual data reported by stakeholders, with the following exceptions:

Country	Input adjusted	Issues identified	Approach adopted
UK	▶ Spectrum concession periods	As explained by the NRA in the comments, the spectrum useful lives reported were based on their national cost model and not on the actual concession period.	Values have been discarded and replaced by publicly available figures.

Table 3.79: Useful lives –Input definition - Adjustments introduced to the data reported [Source: Axon Consulting]

Finally, the table below summarises the list of countries for which spectrum concession periods have been set at country level or as an EEA average[45]:

Resource category	Country specific	EEA average
LIC.Licence 700 FDD.MHz	CZ, DK, FI, FR, DE, LV, LT, MT, NL, RO, SI, UK	AT, BE, BG, HR, CY, EE, EL, HU, IE, IT, NO, PL, PT, SK, ES, SE
LIC.Licence 800 FDD.MHz	AT, BE, HR, CY, CZ, DK, FI, FR, DE, HU, IE, LV, LT, MT, NL, PL, PT, RO, SK, SI, ES, SE, UK	BG, EE, EL, IT, NO
LIC.Licence 900 FDD.MHz	AT, BE, BG, HR, CY, CZ, DK, FR, DE, HU, IE, LV, LT, MT, NL, NO, PL, PT, RO, SK, SI, ES, SE, UK	EE, FI, EL, IT
LIC.Licence 1800 FDD.MHz	AT, BE, BG, HR, CY, CZ, DK, FR, DE, HU, IE, LV, LT, MT, NL, PL, PT, RO, SK, SI, ES, SE, UK	EE, FI, EL, IT, NO
LIC.Licence 2100 FDD.MHz	AT, BE, BG, HR, CY, CZ, DK, FR, DE, HU, IE, IT, LV, LT, MT, NL, NO, PL, PT, RO, SK, SI, ES, UK	EE, FI, EL, SE
LIC.Licence 2600 FDD.MHz	AT, BE, CY, CZ, DK, FI, FR, DE, HU, LV, LT, MT, NL, PL, PT, RO, SK, SI, ES, SE, UK	BG, HR, EE, EL, IE, IT, NO

Table 3.80: Useful lives –Input definition – Source of the useful lives defined for spectrum elements in the cost model [Source: Axon Consulting]

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

Question 10: Do you agree with the validation, treatment and definition of the useful lives for spectrum elements? If you don't, please justify your position and provide supporting information and references.

3.1.15. 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.

3.1.15.1. 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	AT, BE, BG, HR, CY, CZ, DK, FI, FR, DE, EL, HU, IE, IT, LV, LT, MT, NL, NO, PL, PT, RO, SK, ES, SE, SI, UK
High-priority information provided	
Not all High-priority information provided	
No information	EE, IS, LI, LU

Table 3.81: WACC - Data availability [Source: Axon Consulting]

Data confidentiality:

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

Table 3.82: WACC - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to NRAs

3.1.15.2. Input validation and treatment

Firstly, it was recognised that there were not clear indications with regards to whether the WACC had to be reported in nominal or real terms in the Data Request Form. Consequently, while some NRAs reported it in nominal terms, others provided it in real terms.

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 performed for DE, LT, NL, PT and UK.

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 5% and 15% 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 ±40% range from the EEA average were classified as outliers. No values were identified outside this range and, therefore, no issues were detected.

3.1.15.3. 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 3.1.15.2 above.

In case no data was provided, or was discarded, the EEA average was considered. This only applied to EE.

3.1.16. 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[46] services.

Equivalently to the approach adopted in the previous cost study, these costs have been 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.

3.1.16.1. Sources of information

All information used to assess wholesale specific costs has been 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 3.2).

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

[46] 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[47]*:*

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

Table 3.83: Wholesale specific costs – Data availability [Source: Axon Consulting]

Data confidentiality:

Confidentiality level	Countries
Confidentiality level 0	AT, CY, DE, LT, UK
Confidentiality level 1	
Confidentiality level 2	BE, BG, CZ, DE, EL, ES, FI, FR, HR, HU, IT, LV, MT, NL, NO, PL, PT, RO, SI, SE, SK

Table 3.84: Wholesale specific costs - Data confidentiality [Source: Axon Consulting]

No confidential information has been disclosed in the model shared with NRAs for consultation. Please refer to the main consultation document for further indications on the treatment given to confidential information in the cost model circulated to NRAs.

3.1.16.2. 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.

[47] Availability per country refers to the availability of data from the operator that provided the higher amount of data for each country.

3.1.16.3. Input definition

As explained, wholesale specific costs are 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 (e.g. dividing the costs attributable to each service type in equal parts). Consequently, the cost assessment has been 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 have been 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 3.85: Traffic/volume elements drivers selected to perform the regressions for each cost category [Source: Axon Consulting from drivers defined in study SMART 2015/0006]

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 has been 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 has been 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 was extracted as an EEA average (excluding outliers) of the data reported by stakeholders, resulting in a value of 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 2017 was considered in the calculation of the equivalent demand in terms of GB and TAPs per operator:

- Data Roaming inbound (EEA)
- Data Roaming inbound (Non-EEA)
- Data Roaming outbound (EEA and 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 has been 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 has been 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 2017 was considered in the calculation of the equivalent demand in terms of GB and TAPs per operator:

- Voice Roaming inbound incoming
- Voice Roaming inbound outgoing
- Voice Roaming outbound incoming
- Voice Roaming outbound outgoing
- 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 has been 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[48]. 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}).

[48] 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.

- *Conversion to TAPs*: A TAP record is generated for each SMS. Therefore, the number of TAPs is equal to the number of SMS.

The demand of the following SMS services for the year 2017 was considered in the calculation of the equivalent demand in terms of GB and TAPs per operator:

- SMS Roaming inbound incoming
- SMS Roaming inbound outgoing
- SMS Roaming outbound incoming
- SMS Roaming outbound outgoing
- SMS Domestic incoming from national
- SMS Domestic incoming from international
- SMS 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.

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.

Additionally, when stakeholders provided detailed cost data per service category, only the traffic related with these service categories was considered in the generation of the regressions.

Step 3: Rejection of outlier values

Once the costs and the traffic drivers to be used to build up the regressions have been 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	46	11	**35**
	CAPEX	11	N/A	N/A
Operation and management	OPEX	43	6	**37**
	CAPEX	12	1	**11**
Data clearing costs	OPEX	47	9	**38**
	CAPEX	5	N/A	N/A
Financial clearing costs	OPEX	45	16	**29**
	CAPEX	3	N/A	N/A
Negotiation and contract management/regulation costs	OPEX	46	4	**42**
	CAPEX	5	N/A	N/A

Table 3.86: 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 study (SMART 2015/0006), only the following cost categories were considered in the model:

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

This is in line 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

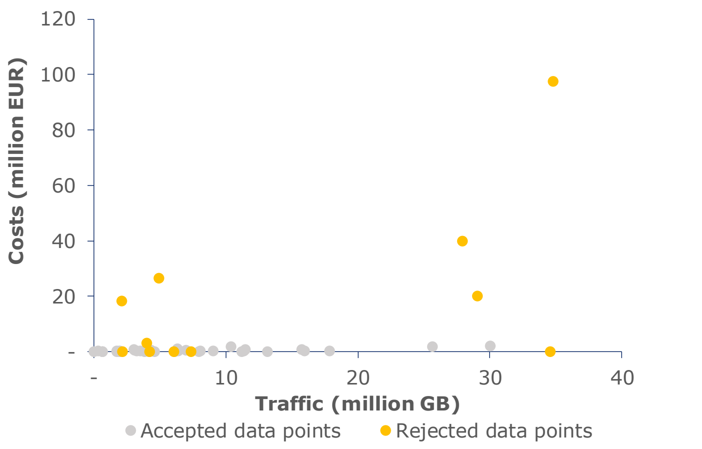
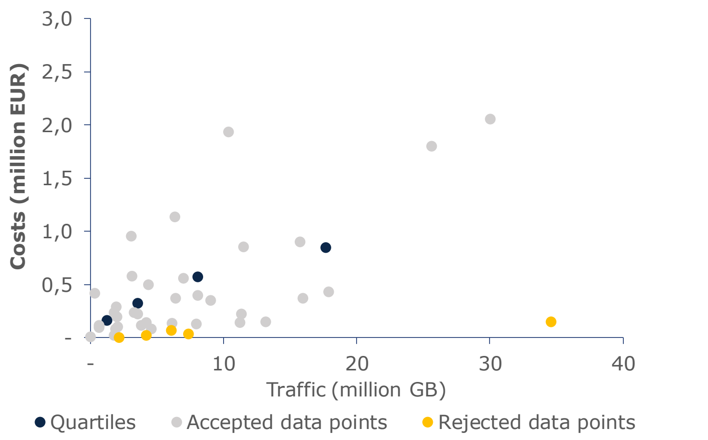
As stated throughout this section, the values to be included in the cost model were extracted from a series of regression analyses for each cost category. This analysis provides the model with a) a fixed cost and b) a variable cost based on traffic.

A linear regression model has been developed consistently with the methodology adopted in the previous cost study. While most stakeholders agreed during the 1st consultation process with the approach followed, we acknowledge that a few of them suggested to consider alternative models (other than linear regression). It is important to note that, during the preparation of the first draft model, several approaches were indeed explored but no evidences were found based on the available information that supported changing the methodology already approved and accepted in the previous cost study.

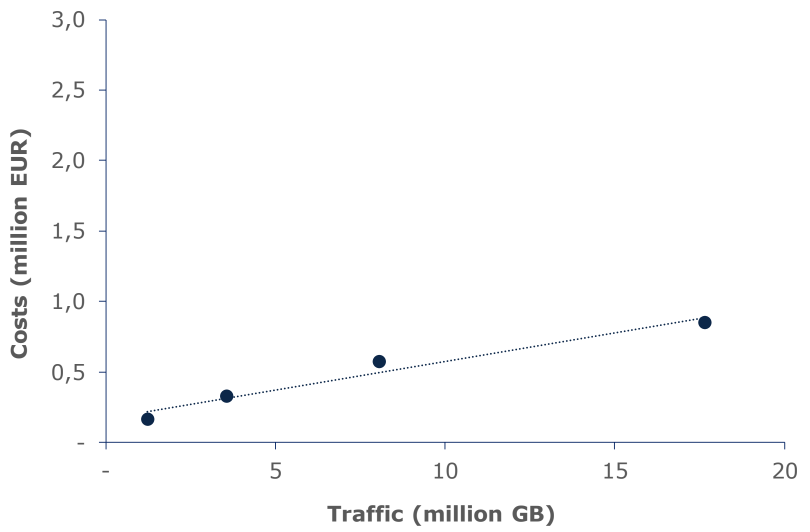
Given the disparity of the references observed for many cost categories, it was complex to identify relevant cost trends were all the references were considered at the same time. Consequently, references were presented in quartiles to better identify the common patterns registered in the different groups 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
	

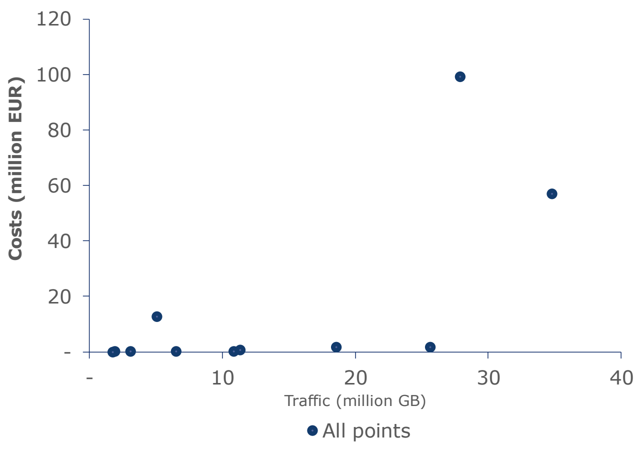
Linear regression based on quartiles



Regression formula	Y = 0.0404x+169,089

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

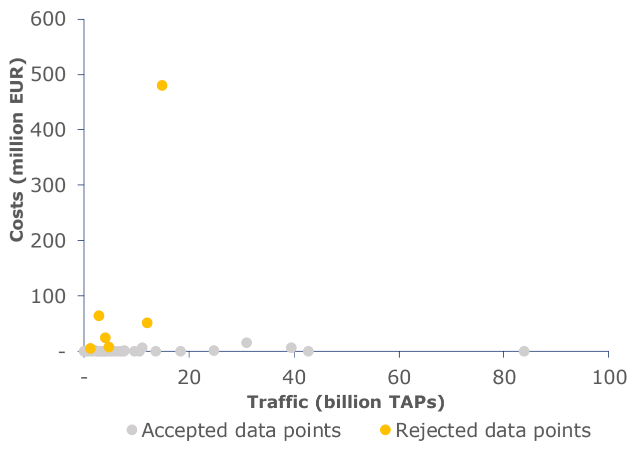
N/A

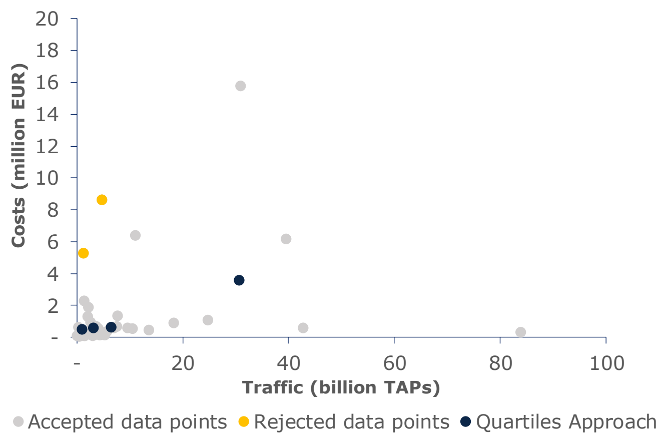
Regression formula	N/A

Cost category	OPERATION AND MANAGEMENT
Cost type	OpEx

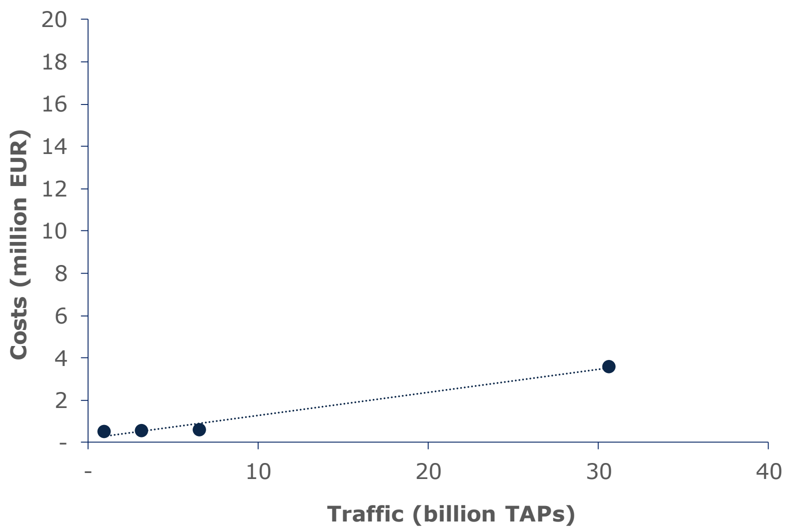
Overview of the references observed

All references	Zoom into the most populated range





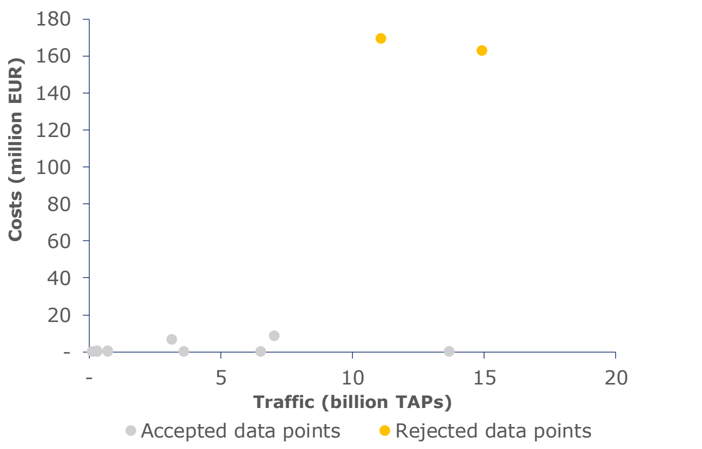
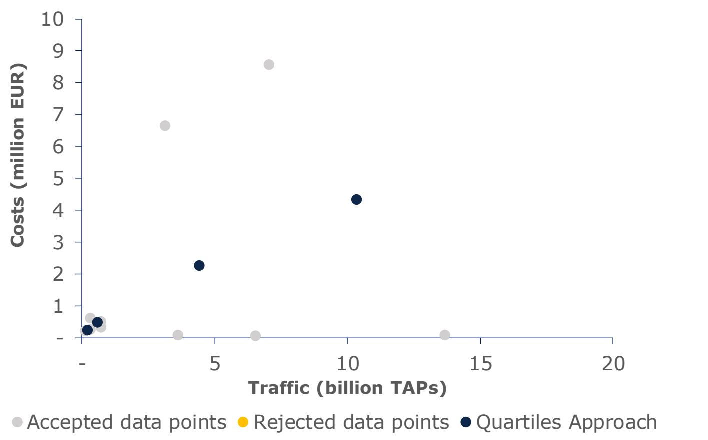
Linear regression based on quartiles



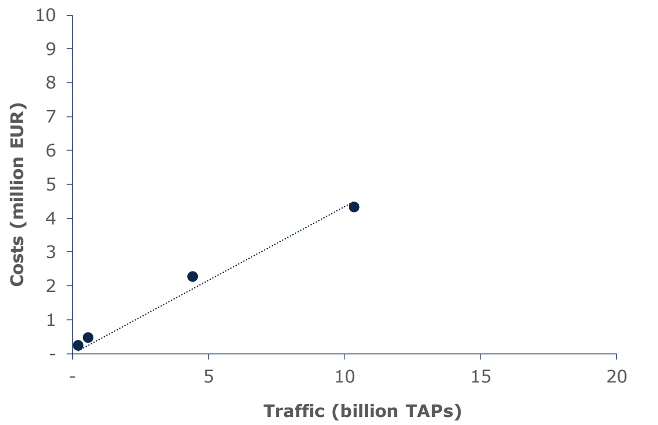
Regression formula	$Y=1.078\cdot10^{-4}x +213{,}250$

Cost category	OPERATION AND MANAGEMENT
Cost type	CapEx

Overview of the references observed

All references	Zoom into the most populated range
	

Linear regression based on quartiles

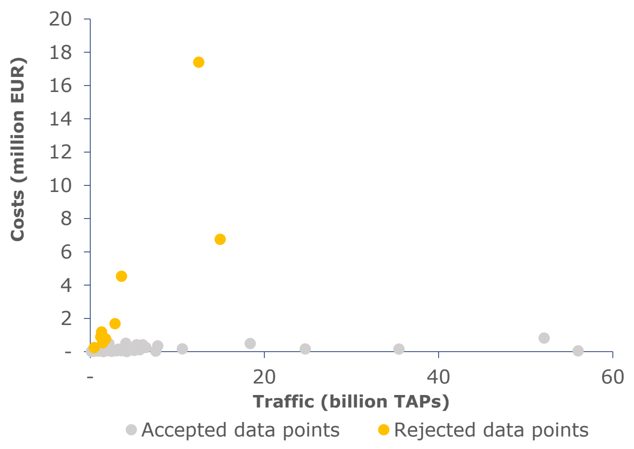
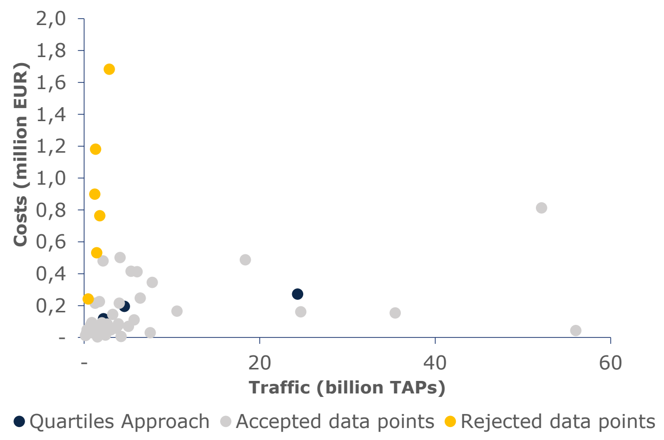


Regression formula[49]	$Y = 4{,}3368 \cdot 10^{-5} x$

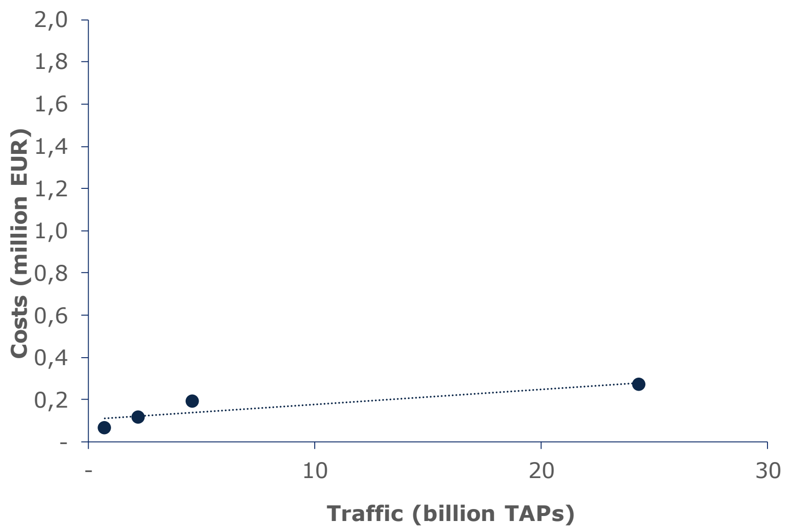
[49] In order to express this element in the model the slope of the regression has been divided by a useful life of 10.

Cost category	DATA CLEARING COSTS
Cost type	OpEx

Overview of the references observed

All references	Zoom into the most populated range
	

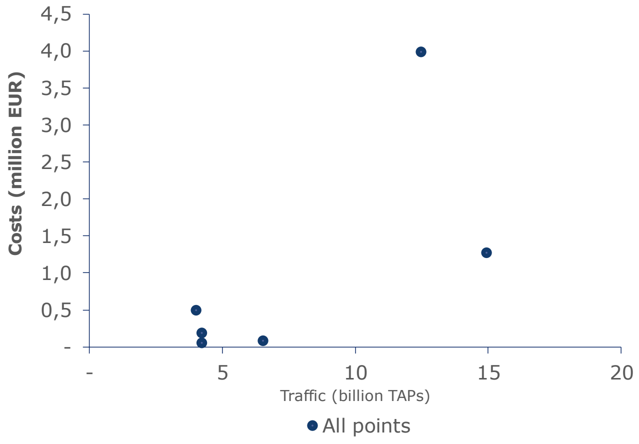
Linear regression based on quartiles



Regression formula	$Y= 7.202 \cdot 10^{-6}x+105,441$

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

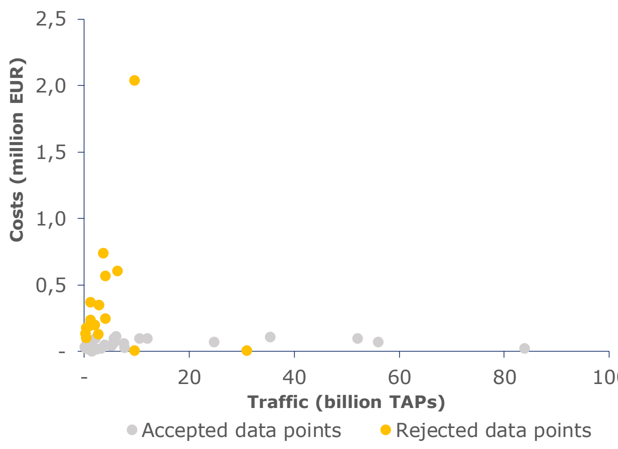
N/A

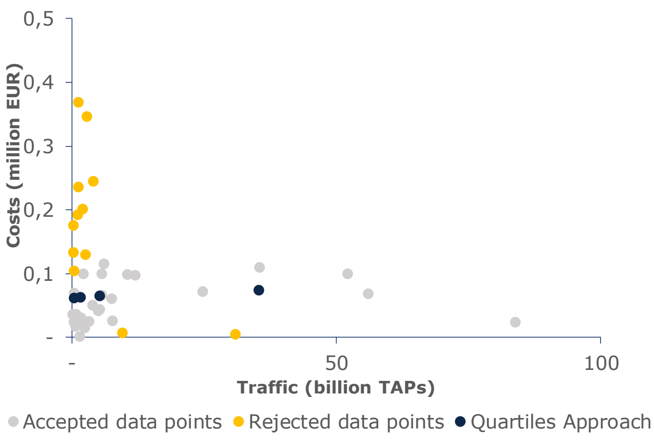
Regression formula	N/A

Cost category	FINANCIAL CLEARING COSTS
Cost type	OpEx

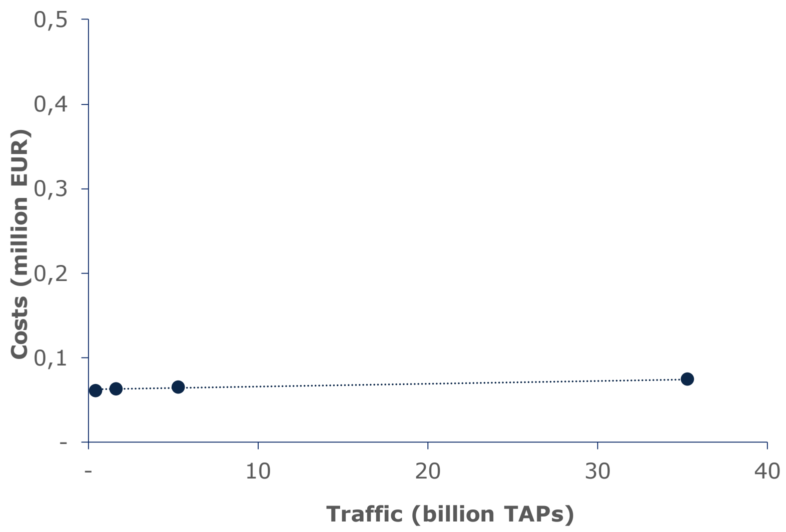
Overview of the references observed

All references	Zoom into the most populated range





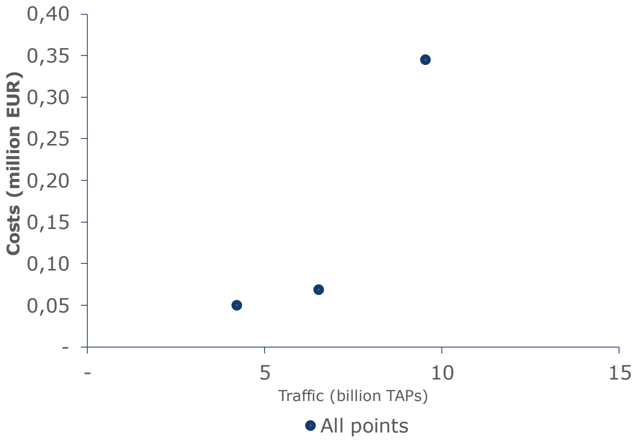
Linear regression based on quartiles



Regression formula	$Y = 3.382 \cdot 10^{-7}x + 62,360$

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

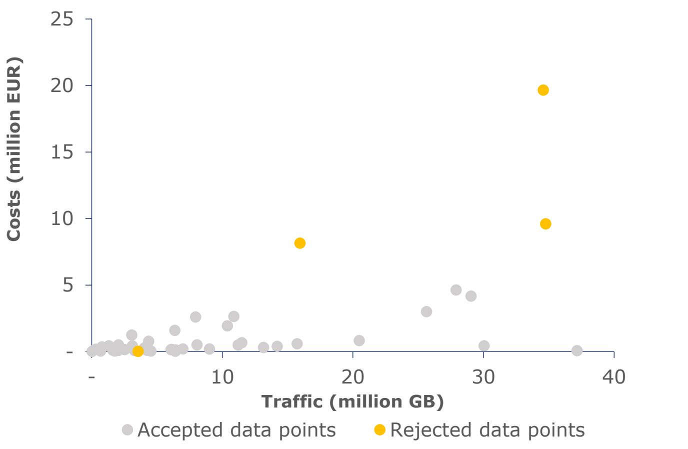
N/A

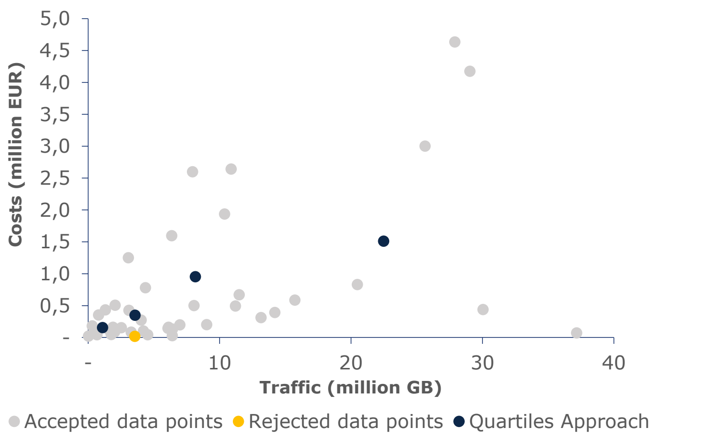
Regression formula	N/A

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

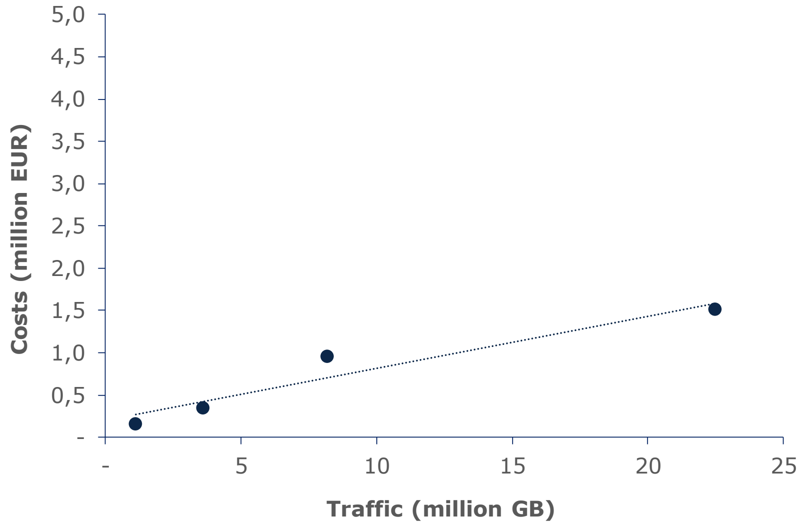
Overview of the references observed

All references	Zoom into the most populated range





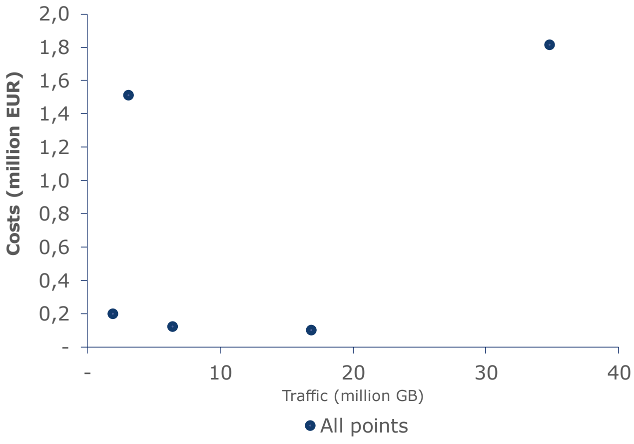
Linear regression based on quartiles



Regression formula	Y= 0,0618x+196,124

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[50]. 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.

[50] 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 has been extracted from the sources described below:

- **Eurostat**: A key source of information was Eurostat's GISCO[51] database. GISCO is a permanent service that provides geographical information at EEA level, its member states and regions. GISCO assigns degrees of urbanization (DEGURBA)[52] 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[53] for 2017[54] and 2012[55]. When no data was available for 2017, 2012 information was used.

- **Geographical information from Geonames.org**[56]: 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

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[51] 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

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

[53] Eurostat database of LAU2 information per country: http://ec.europa.eu/eurostat/web/nuts/local-administrative-units

[54] LAU 2 information per country year 2017: http://ec.europa.eu/eurostat/documents/345175/501971/EU-28_LAU_2017_NUTS_2016.xlsx

[55] LAU 2 information per country year 2012: http://ec.europa.eu/eurostat/documents/345175/501971/EU-28_2012.xlsx

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

the information available at GISCO, we designed a step by step methodology that was both straightforward and reviewable (see section 3.2.2.1).

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 for the year 2017.

In some countries, 2012 LAU information had to be used due to the reasons presented below:

Reason	Countries
Not possible to match GISCO information with LAU2 2017 data	BG, UK
LAU 2 information not available for 2017	CY, DE, FR, IE

Table 3.87: Geographical inputs – Population and area per geotype – Usage of LAU2 2012 information [Source: Axon Consulting]

Note that in these cases the population per municipality and geotype has been adjusted to make the total population reflect the 2017 population of the country.

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, EE, FI, FR, HU, LV, LT and NL. 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 3.88: 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[57].

Country	AREA			POPULATION		
	Urban	Suburban	Rural	Urban	Suburban	Rural
Austria	929	8.787	63.443	2.948.691	2.563.596	3.177.812
Belgium	1.504	14.414	14.611	3.216.287	6.563.964	1.530.849
Bulgaria	2.305	8.108	100.582	3.089.676	1.727.150	2.336.974
Croatia	1.239	10.567	34.550	1.365.758	1.359.067	1.465.875
Cyprus	419	620	5.270	436.240	250.473	161.587
CZ Republic	2.151	10.241	66.479	3.194.782	3.594.332	3.764.686
Denmark	785	13.341	29.036	1.767.974	2.051.459	1.887.867
Estonia	267	1.970	41.228	577.423	299.112	439.366
Finland	12.677	76.392	222.239	2.124.754	1.888.981	1.473.565
France	26.164	30.886	492.010	30.471.227	14.539.401	21.749.371
Germany	17.733	112.970	222.681	28.782.787	35.986.206	17.406.707

[57] With the exception of Iceland, Liechtenstein and Luxembourg, as they did not participate in this cost study.

Country	AREA			POPULATION		
	Urban	Suburban	Rural	Urban	Suburban	Rural
Greece	3.988	36.023	91.901	5.246.380	2.863.184	2.674.136
Hungary	794	13.725	78.494	3.087.719	3.646.654	3.096.126
Ireland	836	2.400	66.675	1.594.641	1.050.930	2.079.129
Italy	14.789	99.829	186.673	20.297.844	29.449.033	10.918.723
Latvia	505	7.533	56.533	860.453	428.273	680.273
Lithuania	826	34.750	29.710	1.251.978	983.511	653.110
Malta	50	265	-	208.333	226.067	-
Netherlands	5.700	18.965	13.159	8.238.519	7.117.422	1.623.159
Norway	4.553	38.550	271.698	1.481.742	2.065.072	1.667.187
Poland	7.451	47.318	254.300	13.081.953	10.685.974	14.199.273
Portugal	4.362	12.349	72.136	4.524.072	3.269.235	2.547.993
Romania	3.700	31.496	177.749	6.905.930	5.127.758	7.726.612
Spain	25.374	109.718	313.909	25.099.864	15.069.297	6.270.939
Sweden	16.261	144.962	286.212	3.974.726	3.948.846	1.927.428
Slovenia	589	5.140	14.545	423.450	779.754	860.996
Slovakia	1.113	7.077	40.726	1.111.009	2.031.197	2.284.094
UK	26.700	31.626	185.287	38.557.520	19.220.125	7.604.955

Table 3.89: 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.

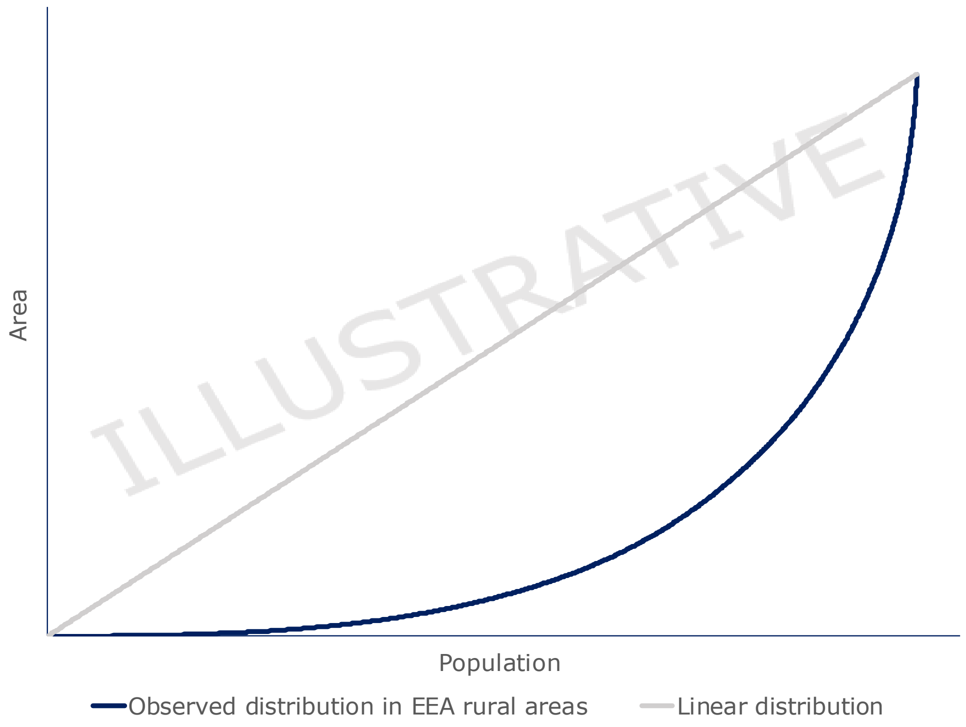

Figure 3.9: Geographical inputs – Distribution of population – Illustrative example of the area and population relationship in rural geotypes [Source: Axon Consulting]

The sections below illustrate the approach adopted to assess how population is distributed in rural areas and the model's inputs that have been 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 have been 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:

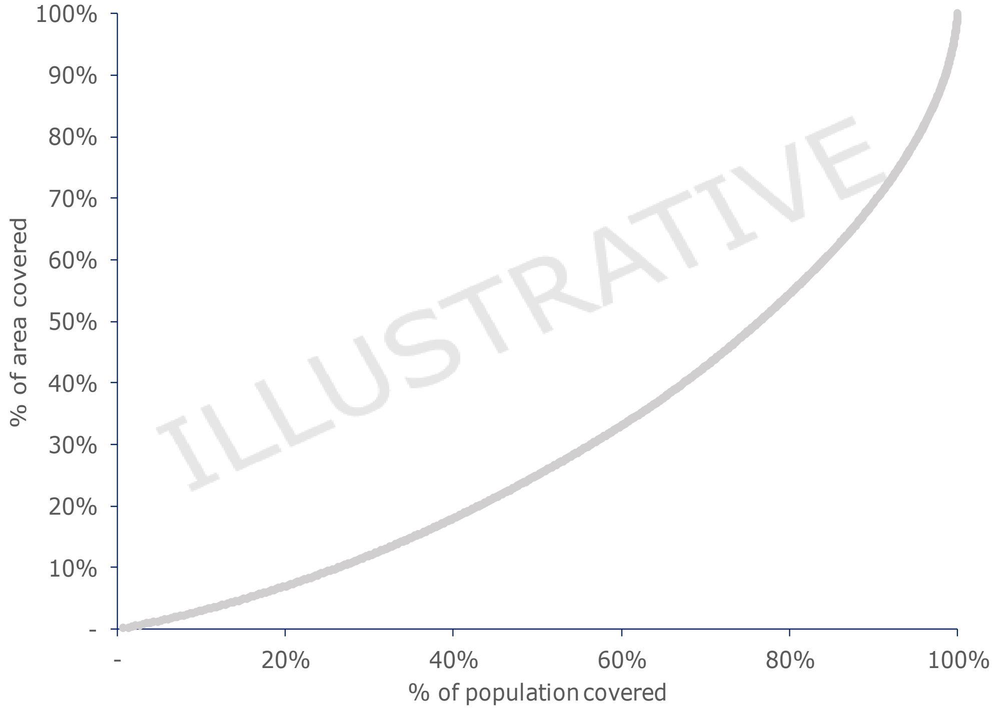

Figure 3.10: Geographical inputs – Distribution of population – Illustrative example of relative area vs population [Source: Axon Consulting]

- *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:

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

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:

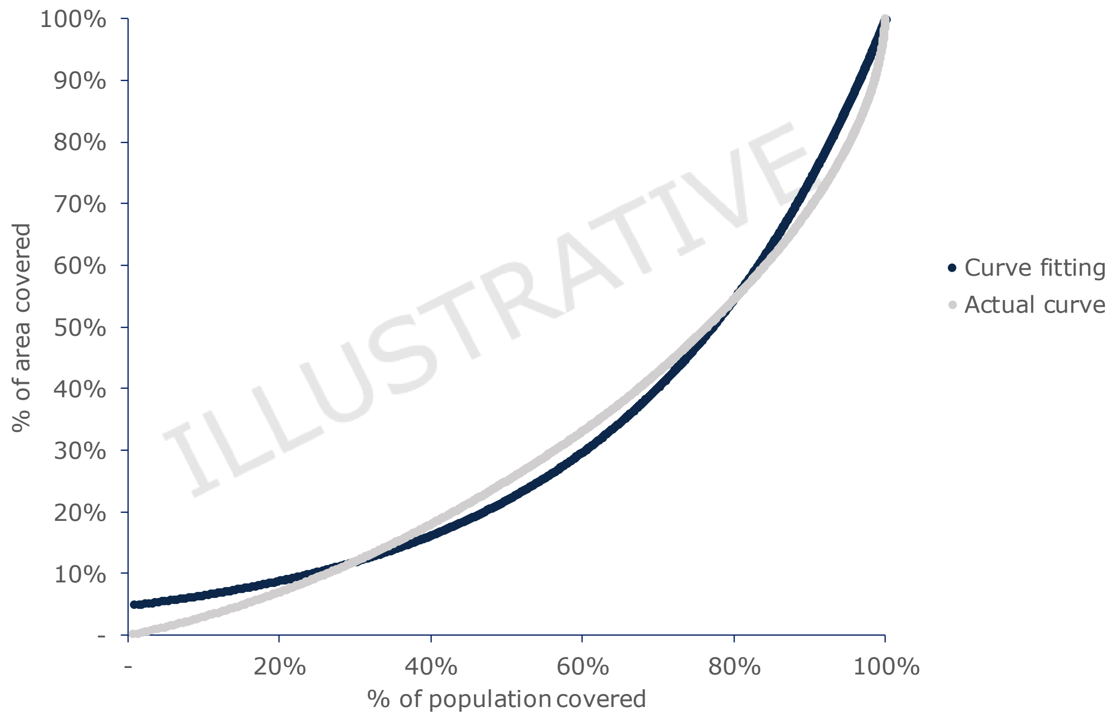

Figure 3.11: Geographical inputs – Distribution of population – Illustrative example of relative area vs population and exponential approximation [Source: Axon Consulting]

- *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
Estonia	3.62	EEA average taken
Finland	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
Iceland	Not participating	
Ireland	3.59	5.10%
Italy	3.32	4.87%
Latvia	3.62	EEA average taken
Liechtenstein	Not participating	
Lithuania	3.62	EEA average taken
Luxembourg	Not participating	
Malta	No rural areas	
Netherlands	3.62	EEA average taken
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
United Kingdom	3.31	2.54%

Table 3.90: 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[58] 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:

[58] The definition of when a rural area is considered to be mountainous is provided below in the methodology section.

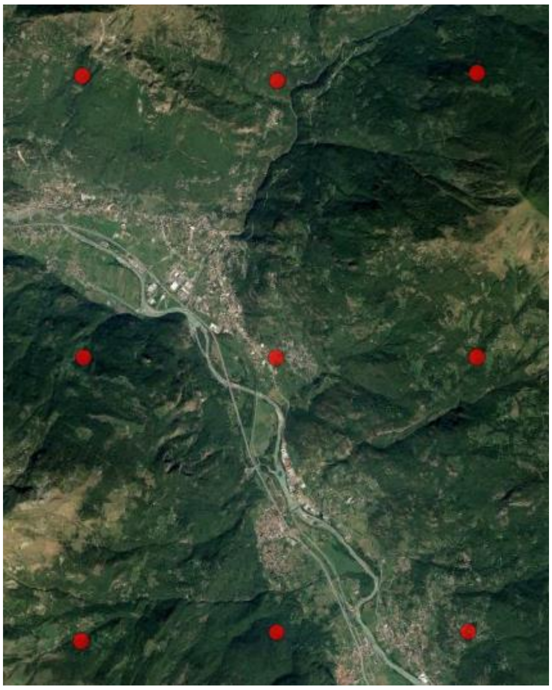

Figure 3.12: Geographical inputs – Topography of the terrain – Points defining the square [Source: Axon Consulting]

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:

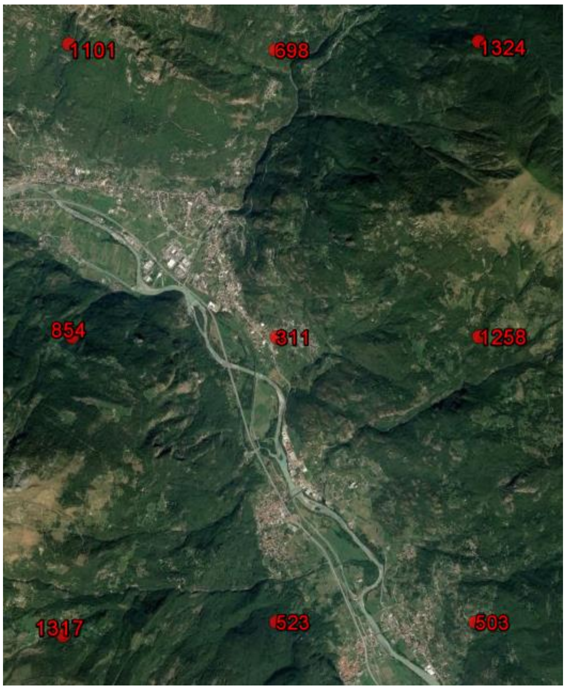

Figure 3.13: Geographical inputs – Topography of the terrain – Height of the points defining the square [Source: Axon Consulting]

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 3500MHz, 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[59] 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.

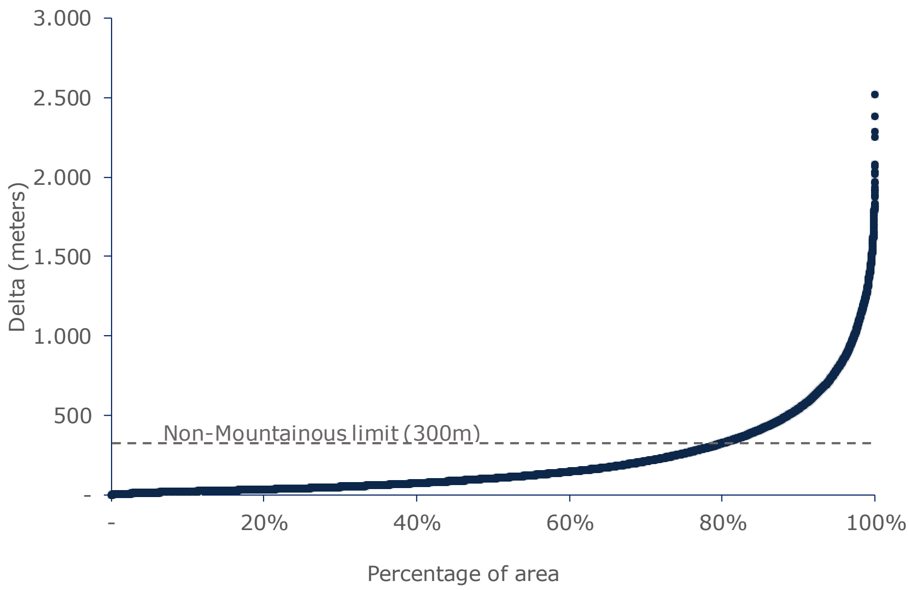

Figure 3.14: Geographical inputs – Topography of the terrain – Delta vs percentage of area [Source: Axon Consulting]

[59] Fresnel zone is a series of concentric prolate ellipsoidal regions of space between and around a transmitting antenna and a receiving antenna system.

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.

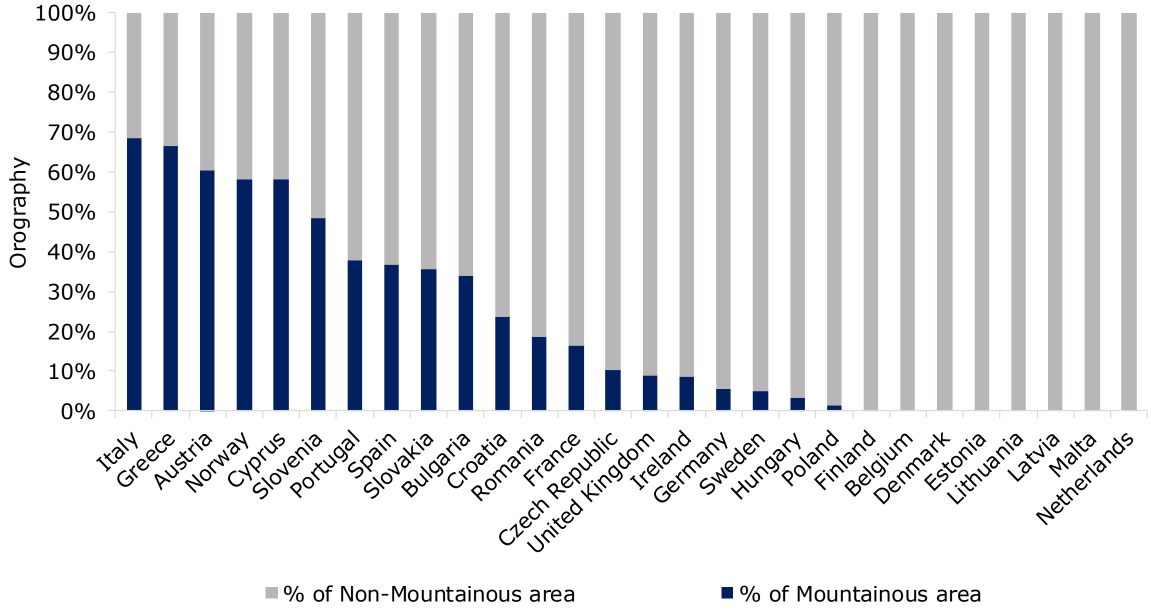

Figure 3.15: Geographical inputs – Topography of the terrain –Percentage of Mountainous/non-mountainous area per country [Source: Axon Consulting]

As shown above, Italy is the most mountainous EU/EEA country in rural areas, while a number of countries including the Netherlands or Latvia are not mountainous at all.

To ease the understanding of the results obtained, the following exhibit illustrates the rural areas that have been considered as mountainous (Blue) and non-mountainous (Yellow):

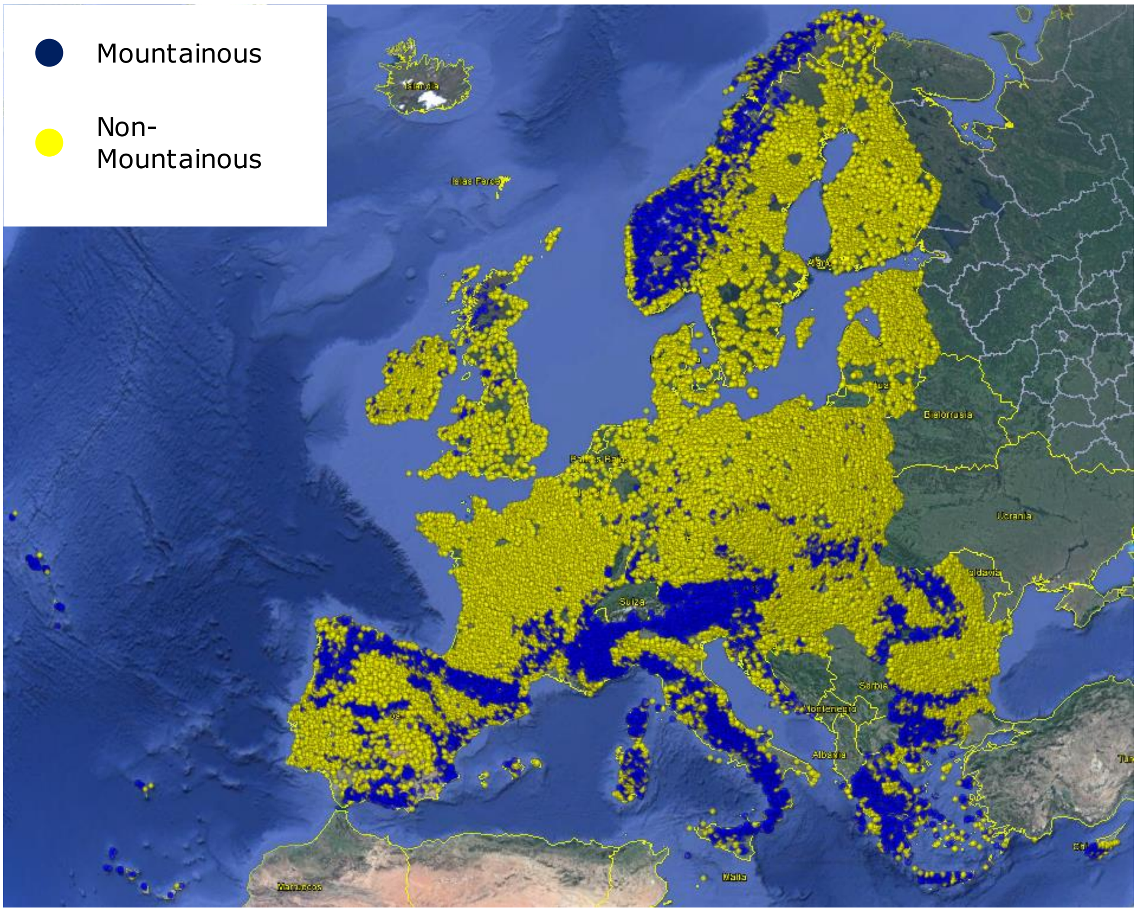

Figure 3.16: Geographical inputs – Topography of the terrain – Mountainous and non-mountainous rural areas in the EU/EEA countries [Source: Axon Consulting]

3.3. Standard industry inputs and low materiality inputs

In addition to all the inputs defined in the previous sections, the model uses a set of 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[60], Eurostat[61])	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 have been 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 have been extracted from network standards, public references or average industry values from Axon's database.

[60] PPP exchange rates from World bank – https://data.worldbank.org/indicator/PA.NUS.PPP?end=2017&start=2016&view=bar&year_high_desc=true

[61] 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.

Figure 3.17: Standard industry inputs and low materiality inputs– Summary [Source: Axon Consulting]

4. 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[62]. The reconciliation assessment performed is described in sections 4.1 and 4.2 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.

Question 11: Do you agree that parameters and scenarios that lead to a mis-reconciliation of the number of assets and/or cost base are not representative and should not be taken into account? If you don't, please justify your position and provide supporting information and references.

Furthermore, they shall expect to receive a summary of the results obtained in each Member State by 27 February.

[62] The reconciliation was assessed on the draft model before the first consultation process and has been reassessed for the second draft model. The results of both reconciliation assessments can be found in the summary presentation that has been shared with stakeholders as part of the second consultation round.

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)

4.1. Network sites

4.1.1. 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.

In order to assess the reconciliation of the model in terms of network sites (i.e. what is the reference between the number of sites calculated by the model and the number of sites in MNOs' networks) the following steps have been adopted:

- **Definition of a reasonable benchmark for comparison**: The first step consisted in the definition of the reference from MNOs that shall be taken into consideration when performing the comparison. This first step comprised the following substeps:
  a) Identification of the number of sites reported by the NRAs in the data collection process and the further details provided in response to the request circulated on 11 December 2018.
  b) Identification of the market share of the MNOs the information provided referred to.
  c) Estimation of the total number of sites in the country by dividing the total number of sites identified in step a) by the market share of the MNOs this information referred to identified in step b).

d) Estimation of the equivalent number of sites of the reference operator, by multiplying the total number of sites in the country estimated in step c) by the market share of the reference operator in that country.

This process was performed for all the countries that provided information to understand their reasonable reference for comparison.

- **Identification of the number of sites produced by the model**: Both worksheets '9G OUT RESULTS – NW' and '10C OUT RESULTS – POLICY' include the number of sites calculated by the Bottom-Up model per country and year. The number of sites presented in both worksheets is the same. Based on that, the reference number of sites produced by the model was extracted from any of these two worksheets for the same year for which the NRAs reported the number of sites in their country.
- **Assessment of the differences between the two references**: The reference for comparison obtained in the first step was finally compared with the reference produced by the model described in the second step to assess the existing differences. As illustrated in the presentation that has been shared with stakeholders, the differences registered were always below ±20%.

Question 12: Do you agree with the approach adopted to assess the reconciliation of the number of sites? If you don't, please justify your position and provide supporting information and references.

4.1.2. Number of sites calculated by the model

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.

Question 13: Do you agree that the number of access sites calculated for the reference operator[63] is reasonable for the operations in your country? If you don't, please justify your position and provide supporting information and references.

[63] Please remember that the reference operator is an operator with the market share defined in worksheet '1A MARKET SHARE', the coverage defined in worksheet '1D INP COVERAGE' and the spectrum defined in worksheet '1E INP SPECTRUM' (apart from other inputs described in this document).

4.2. Cost Base

4.2.1. Reconciliation assessment

The assessment of the reconciliation of the cost base produced by the model to the MNOs' realities was performed following the steps described below, equivalent to those described for the assessment of the reconciliation of the number of sites:

- **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 2017. 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.
    - 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. Only 13% of the references received were discarded for such reasons.
    - 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[64]
- Marketing and sales 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. Only 14% of the references received were discarded for such reasons.

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' depreciation, 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**: Worksheet '9A OUT SERV LRIC TOT COST' includes the detailed cost components that were calculated by the model for a given country, separated between OpEx and depreciation, per year. Based on that, the reference cost base (OpEx[65] + depreciation) was extracted from this worksheet for the year 2017. As described

- **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

[64] It should be noted that the assessment of the reconciliation of the cost base was performed net of G&A expenses.

[65] Without G&A expenses.

existing differences. As illustrated in the presentation that has been shared with stakeholders, the differences registered were always below ±20%.

Question 14: Do you agree with the approach adopted to assess the reconciliation of the cost base? If you don't, please justify your position and provide supporting information and references.

4.2.2. 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.

This information is presented in EUR for all the countries and is obtained from worksheet '9A OUT SERV LRIC TOT COST' of the model.

Question 15: Do you consider that the annual cost base produced for the reference operator[66] is reasonable for the operations in your country? If you don't, please justify your position and provide supporting information and references.

4.3. Roaming data costs per year and country (EUR/GB)

The table "Roaming data costs per year and country (EUR/GB)" in worksheets '9G OUT RESULTS – NW' and '10C OUT RESULTS – POLICY' illustrates the roaming-in (within the EU/EEA) data costs per year in EUR/GB. 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 5.

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.

[66] Please remember that the reference operator is an operator with the market share defined in worksheet '1A MARKET SHARE', the coverage defined in worksheet '1D INP COVERAGE' and the spectrum defined in worksheet '1E INP SPECTRUM' (apart from other inputs described in this document).

Question 16: Do you consider that the unit costs obtained for the roaming-in data service (within the EU/EEA) are reasonable for an operator with the scale of the reference operator[66] in your country? If you don't, please justify your position and provide supporting information and references.

4.4. 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.

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.

Stakeholders will also find a comparison between the voice termination costs produced in the EC's cost model and those produced by some NRAs, including the main drivers of the differences registered, in the presentation that has been shared as part of the second consultation.

Question 17: Do you consider that the unit costs obtained for the voice termination service are reasonable for an operator with the scale of the reference operator[66] in your country? If you don't, please justify your position and provide supporting information and references.

4.5. 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 5, 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.

Question 18: Do you consider that the unit costs obtained for the roaming-in voice service (within the EU/EEA) are reasonable for an operator with the scale of the reference operator[66] in your country? If you don't, please justify your position and provide supporting information and references.

5. Transit charges

5.1. 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 has analysed the transit payments made by visited telecoms operators when providing wholesale roaming services. In addition to the comments received from stakeholders on transit payments during the first consultation, the EC has also reviewed the information provided by operators on transit payments in the context of BEREC's 21st International Roaming Benchmark Report. The EC would like to use the 2nd consultation on the cost model developed by Axon to gather stakeholders' views on its preliminary findings. The

EC welcomes any views and comments from NRAs and operators on this particular issue, which will also inform the EC's decision on the need for a review of the wholesale roaming price caps in the Roaming Regulation.

5.2. The approach followed by the EC to estimate transit charges

In line with the approach followed in the previous review of the roaming rules, the EC has requested information to operators on the transit charges they pay for wholesale roaming traffic in the context of the 21st BEREC International Roaming Benchmark Report. The information gathered in the Benchmark Report showed significant variations in the charges provided by operators. For this reason, the EC used the 1st consultation to request views and comments on the EC's preliminary estimates of transit charges. In parallel, the EC requested NRAs to further enquire with their national operators to understand the reasons for the discrepancies in the estimates 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 (i) previous 2016 roaming review[67]; (ii) first consultation round; and (iii) second consultation round.

[67] For a detailed description of the estimates of transit charges used in the previous review of the roaming rules, please see the EC's 2016 Report from the Commission to the European Parliament and the Council on the review of the wholesale roaming market, available here.

	Voice	Data
Estimates previous roaming review	0.4 EURcent/min	2 EUR/GB
Preliminary estimates - 1st consultation	0.2-0.4 EURcent/min	0.1-0.3 EUR/GB
Preliminary estimates – 2nd consultation	0.4-0.6 EURcent/min	0.1-0.2 EUR/GB

Figure 5.1: Estimates of transit charges paid by wholesale roaming operators [Source: European Commission]

The preliminary estimates for the second consultation are based on the information provided by operators so far in the context of the 21st BEREC International Roaming Benchmark Report and the follow-up inquiries conducted in parallel to the first consultation by the EC with the help from NRAs.

As a result of this follow-up analysis, the EC has reviewed slightly upwards its estimate of average transit payments for voice and slightly downwards its estimate of average transit payments for data services. In addition, the following considerations seem relevant to assess the likely future transit payments for voice and data services:

- Voice transit services: transit payments in the case of voice services are likely to benefit from increased price transparency following the introduction of single maximum fixed and mobile termination rates across the EU (hereafter, Eurorates), as requested by the European Electronic Communications Code for end of 2020. Currently, transit payments include a fee for the transit service and a fee for the termination rate charged by the terminating network operator. As termination rates diverge significantly between EU countries, originating operators have difficulties in understanding which share of the transit fee paid to international transit carriers corresponds to the transit service and which to the termination charge. The introduction of Eurorates is likely to improve the price transparency in the market, facilitating mobile operators' understanding of the transit prices paid to international transit carriers. The EC considers that this is likely to improve the dynamics of competition in the market and, ultimately, tend to reduce voice transit prices. In addition, the increases in consumer demand from both the introduction of RLAH and the new regulation on intra-EU calls in 2019, is also likely to bring prices down for this service.
- Data transit services: the introduction of RLAH has resulted in significant increases in mobile broadband consumption while roaming. This has resulted in very significant declines in the prices paid by operators for data transit services, as shown by the replies from operators to the 21st Benchmark Report. The EC expects this trend to continue over the next years.

Question 19: Do you agree with the EC's preliminary estimates of voice and mobile data transit charges, namely 0.4-0.6 EUR cents/min and 0.1-0.2 EUR/GB, respectively? Otherwise, please indicate your estimate(s) for transit charges and provide evidence supporting your estimate(s).

6. Summary of questions

This section includes a list of the questions raised throughout this document, as a reference for the reader.

These questions have been included in the template to submit stakeholders' answers, which is to be observed and used by all stakeholders who wish to participate in this process.

#	Question	Section
1	**Question 1:** In your opinion, what scenario should be adopted to forecast the traffic split per technology? Please describe your preferred approach in detail and provide supporting information and references.	2.2
2	**Question 2:** In your opinion, what option should be used in defining the increments considered in the model? Please, describe your preferred approach in detail together with its rationale, as well as provide supporting information and references.	2.4
3	**Question 3:** Do you agree that cell radii values in EU/EEA countries should be broadly consistent? If not, please describe in detail the factors that you believe could explain the large discrepancies observed in the figures collected from the different Member States.	2.6
4	**Question 4:** In your opinion, what cell radii scenario should be adopted? Please justify your preferred approach in detail and provide supporting information and references for the preferred cell radii levels as well as the reconciliation in number of sites with real MNOs.	2.6
5	**Question 5:** Do you consider appropriate to maintain as our base case scenario a 50% threshold to identify municipalities as seasonal (as described above), in line with the approach adopted in the first consultation? If you don't, please justify your position and provide supporting information and references.	2.7
6	**Question 6:** In your opinion, what domestic data demand forecast scenario do you expect to better represent the traffic evolution in your country? Please, describe your preferred approach in detail and provide supporting information and references.	2.8
7	**Question 7:** Do you agree with the validation, treatment and definition of the unit cost inputs defined for access sites and Single RAN equipment? Otherwise please describe your rationale in detail and provide supporting information and references.	3.1.6

#	Question	Section
8	**Question 8:** Do you agree with the validation, treatment and definition of the traffic distribution per technology inputs defined for the "Country specific projections" scenario? Otherwise please describe your rationale in detail and provide supporting information and references.	3.1.8
9	**Question 9:** Do you agree with the validation, treatment and definition of the cell radii inputs under both scenarios defined? If you don't, please justify your position and provide supporting information and references.	3.1.11
10	**Question 10:** Do you agree with the validation, treatment and definition of the useful lives for spectrum elements? If you don't, please justify your position and provide supporting information and references.	3.1.14
11	**Question 11:** Do you agree that parameters and scenarios that lead to a mis-reconciliation of the number of assets and/or cost base are not representative and should not be taken into account? If you don't, please justify your position and provide supporting information and references.	4
12	**Question 12:** Do you agree with the approach adopted to assess the reconciliation of the number of sites? If you don't, please justify your position and provide supporting information and references.	4.1.1
13	**Question 13:** Do you agree that the number of access sites calculated for the reference operator is reasonable for the operations in your country? If you don't, please justify your position and provide supporting information and references.	4.1.2
14	**Question 14:** Do you agree with the approach adopted to assess the reconciliation of the cost base? If you don't, please justify your position and provide supporting information and references.	4.2.1
15	**Question 15:** Do you consider that the annual cost base produced for the reference operator is reasonable for the operations in your country? If you don't, please justify your position and provide supporting information and references.	4.2.2
16	**Question 16:** Do you consider that the unit costs obtained for the roaming-in data service (within the EU/EEA) are reasonable for an operator with the scale of the reference operator[66] in your country? If you don't, please justify your position and provide supporting information and references.	4.3
17	**Question 17:** Do you consider that the unit costs obtained for the voice termination service are reasonable for an operator with the scale of the reference operator[66] in your country? If you don't, please justify your position and provide supporting information and references.	4.4

#	Question	Section
18	**Question 18:** Do you consider that the unit costs obtained for the roaming-in voice service (within the EU/EEA) are reasonable for an operator with the scale of the reference operator[66] in your country? If you don't, please justify your position and provide supporting information and references.	4.5
19	**Question 19:** Do you agree with the EC's preliminary estimates of voice and mobile data transit charges, namely 0.4-0.6 EUR cents/min and 0.1-0.2 EUR/GB, respectively? Otherwise, please indicate your estimate(s) for transit charges and provide evidence supporting your estimate(s).	5.2

Table 6.1: Summary of public consultation questions [Source: Axon Consulting]

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.

For a more detailed explanation, please refer to the GISCO study[68].

[68] Eurostat methodology to define the degree of urbanization: http://ec.europa.eu/regional_policy/sources/docgener/work/2014_01_new_urban.pdf

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