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# Guidelines on cost modelling

## Economic policies and methods of determining the costs of services related to national telecommunication/ICT networks

ITU-D Question 4/1

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**Guidelines on cost modelling: Economic policies and methods of determining the costs of services related to national telecommunication/ICT networks (ITU-D Question 4/1)**

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These guidelines were prepared in response to Question 4/1: Economic policies and methods of determining the costs of services related to national telecommunication/ICT networks under the overall guidance and coordination of the management team of ITU-D Study Group 1 led by Ms Regina Fleur Assoumou-Bessou (Côte d'Ivoire), as Chairman, supported by the following Vice-Chairmen: Ms Sameera Belal Momen Mohammad (Kuwait); Mr Amah Vinyo Capo (Togo); Mr Ahmed Abdel Aziz Gad (Egypt); Mr Roberto Hirayama (Brazil); Mr Vadim Kaptur (Ukraine); Mr Yasuhiko Kawasumi (Japan); Mr Sangwon Ko (Republic of Korea); Ms Anastasia Sergeyevna Konukhova (Russian Federation); Mr Víctor Martínez (Paraguay); Mr Peter Ngwan Mbengie (Cameroon); Ms Amela Odobašic (Bosnia and Herzegovina); Mr Kristián Stefanics (Hungary) (resigned in 2018); and Mr Almaz Tilenbaev (Kyrgyzstan).

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## Abstract

These final guidelines on cost modelling were elaborated under ITU-D Question 4/1 on economic policies and methods of determining the costs of services related to national telecommunication/ ICT networks, including next-generation networks.

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# Abbreviations and acronyms

| Abbreviation | Term |
|---|---|
| BDT | ITU Telecommunication Development Bureau |
| BU | bottom-up |
| CAPEX | capital expenditures |
| CAPM | capital asset pricing model |
| CCA | current cost accounting |
| EC | European Commission |
| EPMU | equi-proportional mark-up |
| EU | European Union |
| FAC | fully allocated costs |
| FDC | fully distributed costs |
| FTTH | fibre-to-the-home |
| G&A | general and administrative expenses |
| GBV | gross book value |
| GRC | gross replacement cost |
| GSM | Global System for Mobile Communications |
| HCA | historical cost accounting |
| ICTs | information and communication technologies |
| IP | Internet Protocol |
| IRG | Independent Regulators Group |
| ITU | International Telecommunication Union |
| KPI | key performance indicator |
| LLU | local loop unbundling |
| LRIC | long-run incremental costs |
| LRIC+ | long-run incremental costs plus common costs |
| LTE | Long-Term Evolution |
| MEA | modern equivalent asset |
| NGN | next-generation network |
| NRA | national regulatory authority |

(continued)

| Abbreviation | Term |
|---|---|
| NRC | net replacement cost |
| OPEX | operational expenditures |
| OSS | operational support systems |
| PT | price trend |
| SMP | significant market power |
| TDM | time-division multiplexing |
| UL | useful life |
| UMTS | Universal Mobile Telecommunications System |
| VULA | virtual unbundled local access |
| WACC | weighted average cost of capital |

# 1 Introduction

The ITU Telecommunication Development Bureau (BDT) published the *Regulatory Accounting Guide* in March 2009.[1] The document provides a comprehensive guide for cost-based regulation, covering topics such as the regulatory framework; defining markets and identifying operators with significant market power (SMP); the objectives of cost accounting; and key parameters and methodologies.

Although the ITU Regulatory Accounting Guide focuses mainly on regulatory accounting systems, it includes concepts that are applicable to all regulatory cost models. It also introduces different types of cost models (such as bottom-up).

Even though the ITU Regulatory Accounting Guide is readily available, however, in the course of the work on ITU-D Study Group 1 Question 4/1, on economic policies and methods of determining the costs of services related to national telecommunication/ICT networks, the Rapporteur and Vice-Rapporteurs have identified a potential knowledge gap in some developing countries. This gap relates to the basics of cost modelling in the context of the rapid evolution of information and communication technologies (ICTs) and associated methodologies. In order to fill this gap, and as discussed during Study Group 1 Rapporteur Group meetings in 2019, the Rapporteur and Vice-Rapporteurs for Question 4/1 proposed the adoption of complementary guidelines that can provide national regulatory authorities (NRAs) and telecommunication/ICT network operators with an additional cost-modelling tool that could be of use in their costing and pricing activities.

These guidelines are intended to complement, not substitute, the ITU Regulatory Accounting Guide, taking into account the extensive changes which have occurred in the digital environment over time, the experience gained in the field of cost modelling for regulatory purposes since 2009 and the latest trends followed by NRAs across the world. In addition, these guidelines are more focused on the specific practical knowledge required for NRAs to implement cost-modelling solutions in their countries. This document presents additional information based on publicly available literature (e.g. ITU, NRA publications) and the expertise of the Rapporteur and Vice-Rapporteurs for Question 4/1. It also considers the final report issued in response to Question 4/1 for the previous ITU-D study period (2014-2017),[2] which presents initial studies of different cost models and new charging methods for telecommunication/ICT services in a next-generation network (NGN) environment. The guidelines focus mainly on mobile and fixed telecommunication networks, although many of the topics covered can also be applied to other telecommunication networks, such as satellite and broadcasting networks.

The objective of these guidelines is to present two main topics associated with cost modelling:

- The most relevant methodological choices for the development of a cost model as well as the most common options implemented by NRAs or telecommunication operators (**section 2**).
- The typical phases involved in the development of a cost-model (**section 3**).

1 ITU. Regulatory Accounting Guide. Geneva, March 2009.
2 ITU. Final Report on ITU-D Study Group 1 Question 4/1 for the study period 2014-2017. Economic policies and methods of determining the costs of services related to national telecommunication/ICT networks, including next-generation networks. Geneva, 2017.

# 2 Methodological choices and common options

A broad range of methodological options are available for the development of cost models. The objective of this section is to introduce the main methodological issues and outline the different choices available, in order to provide NRAs, telecommunication/ICT network operators and service providers with appropriate guidance on the implementation of cost models.

When determining the methodology for the development of cost models, the following main aspects should be addressed:

- Costing approach
- Cost standard
- Cost elements
- Treatment of capital-related costs
- Treatment of revenues
- Definition of the reference operator
- Services and increments
- Network topology design
- Geographical modelling

## 2.1 Costing approach

From a high-level perspective, there are two main cost-modelling approaches that can be used:

- **Top-down cost models:** These models are built up starting from an operator's general ledger and balance sheet. Based on a number of steps (generally two or three, although more complex models can be also adopted) and allocation criteria, costs are distributed across the end services. Top-down models ensure full reconciliation with the operator's costs, except for cost-of-capital allowances and potential revaluations of assets. As such, they do not allow NRAs to identify potential inefficiencies in their operations and are not fit for calculating the costs of hypothetical (efficient) operators. Although they can be used for forecasting, top-down models are less flexible than bottom-up cost models, and thus less suitable for that purpose.

  In practical terms, top-down models (in any of their various forms, such as accounting separation or regulatory accounting) are typically implemented and updated by operators – not by NRAs – as they require a significant amount of information that is difficult for an NRA to gather. However, it is quite common that, when an NRA requests the development of such a model (e.g. as a remedy imposed as a result of a market analysis), the regulator audits/reviews each year's results to ensure that they are accurate and comply with the regulations in place (or commissions a third party to do so).
- **Bottom-up cost models:** These models are built up starting from a set of basic inputs (e.g. demand, coverage, geographical and technical information). Based on these inputs, bottom-up models dimension the required network to fulfil coverage and capacity requirements using technical engineering algorithms. The network costs are then calculated as the product of the number of network elements and their unit cost. Capital expenses are depreciated according to the methodology selected. These costs are subsequently allocated to services, based on a predefined set of criteria.

  This approach does not reconcile exactly with an operator's financial accounts, but it can (and should) be properly designed to accurately represent operations in the country. Bottom-up models allow the calculation of forecasts, what-if analyses, different scenarios, and so forth. In addition, they can be used to calculate the costs of a reference operator

that does not exist in the market (hypothetical operator).[3] However, non-network costs that are associated more with human resources than with investment (especially retail costs) can be difficult to model through a bottom-up approach. Unlike top-down models, bottom-up models can be developed by both NRAs and operators, as they require less data from the operators. When the model is used for regulatory purposes, it is typically developed by the regulator, providing NRAs with more control over the methodologies applied.

## 2.2 Cost standard

The cost standard defines how costs are to be allocated to services. There are three[4] commonly-accepted alternatives,[5] namely:

- **Fully allocated costs (FAC)**: Attributes the costs (including common and joint costs) to services based on each service's utilization of the different cost elements (i.e. table of routing factors).
- **Pure long-run incremental costs (pure LRIC)**: Calculates the costs that would be saved if certain services, groups of services or activities (defined as an increment) were not provided. These incremental costs are aligned with the variable costs in the long run. In this approach, neither common costs nor joint costs are allocated to the services.
- **Long-run incremental costs plus common costs (typically known as LRIC+)**: Unlike the pure LRIC approach, LRIC+ allows for the recovery of common and joint costs that are not incremental to any given service (added on top of pure LRIC).

Generally speaking, while the FAC methodology is still commonly adopted in the development of top-down cost models owing to its ease of implementation and practicality, an LRIC approach is typically implemented in bottom-up models. Based on the above definitions, it is clear that the choice of a pure LRIC or LRIC+ cost standard is dependent on the intended treatment of common and joint costs, in particular on whether or not certain services should bear part of these costs.

It is widely accepted that wholesale access services (one-way interconnection, such as access to the local loop, access to passive infrastructure, voice origination, bitstream services, leased lines, etc.) must bear a fair share of common and joint costs.

A debate among academics and regulators has taken place in recent years about whether it is appropriate to allocate common and joint costs to two-way interconnection services (such as fixed and mobile voice termination). Following a recommendation of the European Commission (EC) on the determination of voice interconnection costs,[6] a majority of European NRAs have implemented the pure LRIC standard. Outside the European Union (EU), the pure LRIC standard is less common (in comparison with LRIC+), although some non-EU countries have also followed the EC recommendations.

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3 An overview of the potential reference operators that can be modelled is provided in section 2.6.

4 The ITU Regulatory Accounting Guide also describes two additional cost standards: *Standalone costs* and *Marginal costs*. However, nowadays these two methodologies are rarely used by NRAs.

5 It should be noted that these standards may be known by different names.

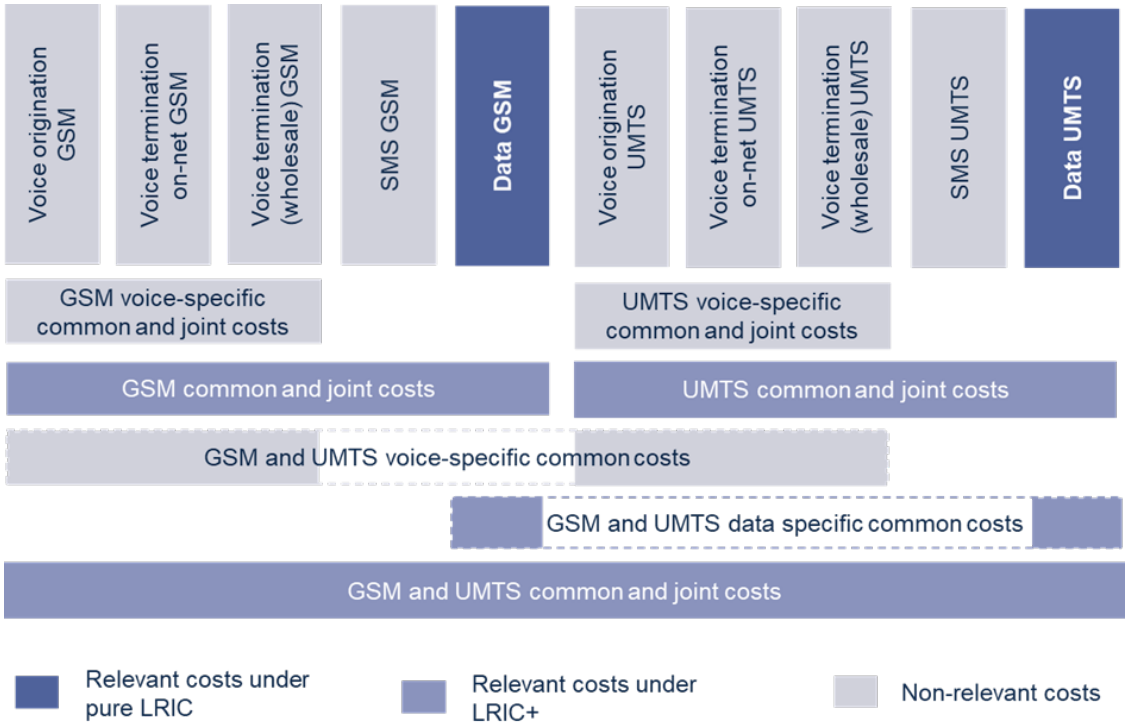
6 EU. EUR-Lex. Commission Recommendation of 7 May 2009 on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU. Official Journal of the European Union L 124/67, 20 May 2009.

As described above, when the LRIC+ standard is adopted, NRAs need to decide how common and joint costs are to be allocated. There are a number of methodologies that can be used for the allocation of common costs, namely:

- **Equi-proportional mark-up (EPMU)**, which allocates common and joint costs to services in proportion to their incremental costs. While the EPMU approach has the advantage of simplicity, it may also present severe limitations, particularly in cases where common and joint costs account for a significant amount of the cost base.

  The EPMU approach may be difficult to use when there are common and joint costs for several increments that may not necessarily be relevant to all services. This is often the case for common and joint costs related to the network. The following figure illustrates this phenomenon in the particular case of a mobile bottom-up long-run incremental cost (BU-LRIC) model, showing how different types of common and joint costs may be relevant to different increments and services:

## Figure 1: Example of relevant incremental costs under both the pure LRIC and LRIC+ standards of data services




It would be inaccurate, in such cases, to allocate all common and joint costs indistinctly based on a simple mark-up of incremental costs alone. The use of combinatorial analysis, whereby different combinations of increments are considered to identify more accurately the costs common only to a subset of increments or services, could provide a possible solution to the problem. This method, however, complicates significantly the design of a cost model and reduces the transparency of cost calculations.

- The **Shapley-Shubik** method consists in setting the cost of a service equal to the average incremental cost of the service after assessing every possible order of arrival of the increment. This approach is based on game theory, but its complexities and unpredictability make it rather uncommon, and very few countries implement it.
- The **Ramsey Pricing** approach recovers common costs from the services based on their relative marginal cost of production and price elasticity. This approach is generally perceived as the most economically appropriate for the recovery of common costs;

however, the data required for calculation has proven to be a considerable obstacle for its implementation.

- **Effective capacity** allocates common and joint costs based on the capacity used by each service at busy hour (i.e. through the table of routing factors). This approach is gaining traction since it is relatively simple to implement and ensures consistency with the services' actual usage of the network assets. Depending on the definition of the increments and on network realities, this approach may yield results using the LRIC+ model that are close or equal to those obtained using the FAC method.

## 2.3 Cost elements

While top-down cost models take into consideration all cost elements recorded in the operators' financial statements, bottom-up models are usually focused on network-related expenses (plus general and administrative costs). The most common cost elements can be classified in the following groups:

- Network costs
- Licence and spectrum fees
- Retail costs
- General and administrative costs (G&A)
- Cost of capital.

These categories are described below.

### 2.3.1 Network costs

In view of their importance, network costs may be divided into network capital expenditures (CAPEX) and network operational expenditures (OPEX). Network CAPEX includes the investment made by operators to deploy their network, such as:

- The purchase of network equipment (e.g. switches), including related software
- Network infrastructure (e.g. buildings, ducts)
- IT support systems, such as network operational support systems (OSS)
- One-off fees for subcontracted network services (e.g. leased-line activation charges)
- Installation costs associated with the items above.

Network OPEX includes the recurrent costs associated with operating the network, such as:

- Network personnel
- Outsourced maintenance services
- Power (electricity and fuel) and other utilities
- Recurrent charges for subcontracted network services (e.g. leased lines, dark fibre)
- Network site rentals.

### 2.3.2 Licences and spectrum fees

Licence costs and spectrum fees[7] may represent a significant cost for telecommunication operators. They have different purposes:

- Licences are related to the permission to provide telecommunication services. They can take the form of an annual or one-off fee, and both options can be considered in the models. They are commonly considered as a non-network common cost and are included in cost models as part of G&A costs. If some of the fees are directly associated with a group of services (e.g. licence for voice telephony), these can be allocated as a mark-up to the applicable services only.
- Spectrum fees cover the rental of a resource that is essential for the network. They can take the form of an annual or one-off fee, and both options can be considered in the cost models. They include both spectrum associated with wireless access and microwave spectrum for transmission. These fees are commonly considered as a network common cost.

### 2.3.3 Retail costs

Retail costs can be divided into the following categories:

- Marketing
- Sales
- Commissions to dealers
- Cost of goods sold (terminals, SIM cards, interconnection payments, etc.).

The cost categories listed above are related to the provision of retail services and should not be allocated to wholesale services. In addition, given the complexities involved in estimating these costs in the bottom-up model, they are not typically included in such models. Retail costs, therefore, are mainly addressed through top-down cost models only.

### 2.3.4 General and administrative costs

General and administrative (G&A) costs are associated with management activities and are common in network and commercial activities (finance, management, etc.).

### 2.3.5 Cost of capital

Service costs need to account for a reasonable amount of return on invested capital that an operator would be able to earn in a truly competitive market. In order to estimate this minimum/expected amount of return, NRAs typically (if not always) use the **weighted average cost of capital (WACC)**, which is defined as the sum of the weighted cost of equity and debt. The weights are based on the market value of equity and debt, respectively.

The use of WACC is by far the preferred mechanism to reflect a minimum/expected regulated profit level in the telecommunication industry and is a *de facto* international standard in the implementation of regulatory cost models.

There is a certain consensus in the industry that WACC should be calculated through the capital asset pricing model (CAPM), based on the following formula:

[7] In some countries, these costs and fees may go by different names, such as application fees, regulatory fees, etc.

$$WACC = \frac{K_e \cdot \frac{E}{E+D}}{1-t} + K_d \cdot \frac{D}{E+D}$$

It can be deduced that the calculation of WACC depends mainly on four key parameters:

**1) Debt and equity shares**, which represents the share of the firm's financing that comes from debt (D) and equity (E)

**2) Cost of equity ($K_e$)**, which represents the annual return expected by shareholders

**3) Tax rate**, which differentiates the fiscal treatment of debt and equity financing

**4) Cost of debt**, which represents the finance costs associated with the firm's debt.

The cost of equity is typically determined through the following formula:

$$K_e = r_f + \beta \cdot ERP$$

Where:

- represents the risk-free rate, i.e. the return on assets that are free of risk;
- represents the levered beta, i.e. the measurement of the historical volatility of an individual stock share relative to its stock market index;
- ERP represents the equity risk premium, i.e. the difference between the annual return expected from equities and a risk-free bond.

Although there is a consensus on the WACC formula, there are differences in how each stakeholder (within a single country and across countries) determines the inputs to be used for calculation.

Therefore, it is highly advisable – and also best international practice – for NRAs to determine WACC at the national level. In particular, NRAs should calculate, on an annual basis, at least one[8] WACC for the fixed telecommunication market and another WACC for the mobile telecommunication market, based on the financial key performance indicators (KPIs) of the service providers operating in their country. Given the changing nature of some parameters used in WACC, this practice will ensure consistency among models and transparency for the sector.

In order to calculate WACC, NRAs should define a robust methodological framework setting out how they will determine the inputs involved in the above-mentioned formula.

## 2.4 Treatment of capital-related costs

One appropriate way of treating CAPEX is to let NRAs decide on the following key methodological aspects, which are described in detail below:

– Asset valuation method

[8] Some countries apply a different WACC for NGA-related assets to account for the additional risk, and others calculate a different WACC for each service provider.

- Consideration of modern equivalent assets
- Annualization method
- Treatment of working capital.

### 2.4.1 Asset valuation method

Generally speaking, there are two alternatives to be considered for valuation of the cost of an asset (i.e. cost references):

- **Historical cost accounting (HCA)** reflects the price paid historically by the company to acquire an asset, based on its accounts.
- **Current cost accounting (CCA)** reflects the current and expected market value of assets. It illustrates the investment associated with building the entire network in the reference year.[9]

The selection of the relevant asset valuation method is highly dependent on the regulatory objectives pursued by the NRA. For instance, HCA may provide appropriate cost references for services that rely on assets unlikely to be replicated by other operators (e.g. civil infrastructure sharing services), while CCA provides the right balance between buy and build decisions (e.g. fibre-to-the-home (FTTH), virtual unbundled local access (VULA)).

Both methods can be used in top-down and bottom-up cost models. The same cost model (top-down or bottom-up) can also be built up under both cost-accounting approaches.

### 2.4.2 Consideration of modern equivalent assets

The concept of forward-looking costs generally requires assets to be valued using a modern equivalent asset (MEA), which is defined by the Independent Regulators Group (IRG) as:[10]

*"The lowest cost asset, providing at least equivalent functionality and output as the asset being valued."*

These assets should correspond to the ones a new operator would be expected to employ to build a new network.

According to the ITU Regulatory Accounting Guide:[11]

*"Modern Equivalent Asset (MEA) should be used whenever it is possible, as it is the most accurate valuation criterion to reflect the cost of an efficient operator, since it will capture the associated costs (and efficiencies) that an entrant/alternative operator would face, if entering into the market at a specific time."*

In addition, NRAs should take into account existing regulations and the services provided by the operators. If an asset is strictly necessary to provide a service because of regulatory obligations, it should not be revalued even though an MEA may exist. For instance, if time-division multiplexing (TDM) legacy interconnection is required, the assets enabling that interconnection should be considered instead of the IP interconnection equivalents.

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9 The ITU Regulatory Accounting Guide, 2009 provides further detail (in section 4.4) about the alternative approaches that can be followed for valuing assets at current costs.

10 Independent Regulators Group (IRG). Principles of implementation and best practice regarding FL-LRIC cost modelling. 24 November 2000.

11 ITU. Regulatory Accounting Guide, 2009 (op. cit.). Section 4.4.1

The decision to use an MEA is especially controversial in the context of access technologies. There are opinions to the effect that legacy access technologies such as 2G/3G and copper pairs should be modelled based on their MEA (4G and passive optical network, respectively). However, this approach is not commonly followed by NRAs since it would deviate significantly from the realities in the country.

### 2.4.3 Annualization method

The pattern of cost recovery over time is heavily dependent on the depreciation methodology adopted.

Although there are multiple depreciation methodologies that are financially accepted, the following four alternatives are the most widespread in regulatory costing exercises:

- **Straight line depreciation** is the most common method in financial accounting. It simply spreads the original cost of an asset evenly across its economic life. The method is popular because of its simplicity but is criticized for not reflecting economic reality. It also ignores the cost of capital, which must be calculated separately (as the product of net book value and WACC). This method presents difficulties in bottom-up models, since the cost of capital in the initial modelling years would be very high (as a bottom-up model would assume that the entire network is built in the first year of the model). The following formula shows how this method would typically be implemented (including cost of capital):

$$Cost = \frac{GBV}{UL} + NBV \cdot WACC$$

  Where:

  - GBV is the gross book value of the asset (which can be substituted by the gross replacement cost (GRC), in the case of current costs);
  - UL is the useful life of the asset;
  - NBV is the net book value of the asset (which can be substituted by the net replacement cost (NRC), in the case of current costs);
  - WACC is the weighted average cost of capital.

- **Standard annuity** also spreads the cost of an asset evenly over its economic life, but takes into account the cost of capital as well. Annuities, therefore, consist of two separate elements: the annualized cost of the asset (depreciation), and the financing or cost of the capital charge. In a standard annuity, the annual charge remains constant over the life of the asset. This method has also been criticized for failing to reflect the true depreciation profile of the asset. The following formula shows how this method would typically be implemented (including both depreciation and cost of capital):

$$Cost = GBV \cdot \frac{WACC}{1 - (1 + WACC)^{-UL}}$$

  Where:

  - GBV is the gross book value of the asset (which can be substituted by the gross replacement cost (GRC), in the case of current costs);
  - UL is the useful life of the asset;
  - WACC is the weighted average cost of capital.

- **Tilted annuity** relaxes the assumption of constant prices. In telecommunication networks, the prices of active equipment tend to fall over time, whereas infrastructure costs (e.g. digging trenches) tend to rise over time. If, for example, the standard annualization method ignored falling prices, entrant 2 would have an advantage over entrant 1 as it would benefit from lower asset prices and consequently lower depreciation charges. When asset prices are falling, a tilted annuity recovers more capital in the early years (and vice versa), which ensures that two entrants with an identical asset base (although acquired in different periods) have identical depreciation charges. Although various formulae may be used for implementing a tilted annuity method, the following formula is fairly typical:

$$Cost = GBV \cdot \frac{WACC - PT}{1 - \left(\frac{1 + PT}{1 + WACC}\right)^{UL}}$$

  Where:

  - GBV is the gross book value of the asset (which can be substituted by the gross replacement cost (GRC), in the case of current costs);
  - UL is the useful life of the asset;
  - WACC is the weighted average cost of capital;
  - PT is the price trend or the rate of price change associated with the asset.

- **Economic depreciation** is defined as the period-by-period change in the market value of an asset. The market value of an asset is equal to the present value of the net cash flow the asset is expected to generate over the remainder of its useful life. As net cash flows vary with output, assets are depreciated at a rate consistent with use, resulting in a true depreciation profile. In practice, given the difficulty of objectively determining economic depreciation, it is commonly approximated by tilting the depreciation based on the amount of output produced by the asset. The main issue then lies in defining the output, which is typically approximated according to traffic. This approach may result in significant backloading of costs. Additionally, a disadvantage of economic depreciation is that present results are affected by output forecasts, bringing further uncertainties. In the case of economic depreciation, there is no clear trend on the formula to be used.

In top-down models, the most common practice is to adopt the same depreciation method as the one considered by the modelled operator in its financial statements in order to maximize consistency between the results of the top-down model and the operator's financial statements. This also means that straight line depreciation is typically used in top-down models.

On the other hand, the tilted annuity approach is the most common annualization method in bottom-up models, as it offers the best balance between economic accuracy and ease of implementation. It allows the evolution of network prices to be considered, while avoiding possible discrepancies due to forecast uncertainty that can affect calculations when the economic depreciation method is used.

In the particular case of European countries, economic depreciation is commonly used for interconnection services since it was recommended by the EC. The recommendation has been extrapolated by most NRAs to other services (such as local loop unbundling (LLU), bitstream, etc.).

At the same time, when pricing services provided over new networks or networks in early stages of deployment, it is economically prudent to take into account the expected evolution of demand in the foreseeable future. Failure to do so would result in unrealistically high unit costs

during the first years of network deployment (due to low demand at the very early stages). Those costs, if reflected in the prices, would depress demand and thus impede the development of future economies of scale. This is why economic depreciation is suitable for the development of networks at an early stage (such as FTTH networks at present).

## 2.5 Treatment of revenues

Revenues are not typically considered in bottom-up models, which are focused on the calculation of network costs for wholesale services.

In the case of top-down models, it is very common to include revenues with a view to producing margins per service. Although revenue allocation is relatively simple, the following main challenges may arise:

- Financial information may not include relevant detail about certain services, and it may be necessary to rely on billing systems for the allocation of revenues to services. In some cases, billing systems may not reconcile fully with the audited financial accounts.
- Bundling is becoming common in the telecommunication sector. In the case of bundles, it may not be obvious how to separate revenues for each of the services included in the bundle (e.g. voice and data). In the countries where a relevant portion of the revenues still comes from pay-per-use tariffs, these tariffs can be used (together with consumption) to separate the revenues for the bundled services. Otherwise, an alternative method should be clearly defined, in agreement with the regulator.

## 2.6 Definition of the reference operator

One of the most important methodological issues to be addressed in the development of bottom-up models[12] is the kind of operator to be modelled, the so-called reference operator(s). One of the following options may be chosen:

- Developing one model for each operator in the market, capturing the most relevant features of the particular operator's activities, such as traffic, available spectrum or coverage. This option may be preferred in markets where there are substantial differences among operators and, in particular, where the regulatory agency considers that asymmetrical wholesale charges are required.
- Developing a model for a hypothetical existing operator (efficient operator),[13] with specific demand, coverage, etc. This option is commonly used in mobile markets where differences between operators are not considered to be substantial enough or where the regulatory agency considers that, should such differences exist, they do not need to be translated into asymmetrical wholesale charges. In these cases, the reference operator is assumed to have a market share (and spectrum in the case of mobile) which represents 1/N, N being the number of network operators in the country.
- Developing a model for a hypothetical new entrant, i.e. a generic reference operator presumed to start operations at a certain date – normally at the start of the modelled period. This option may be a reasonable choice in nascent mobile markets or in cases where the regulatory agency wishes to establish price signals aimed strictly at promoting efficient new entry.

[12] It should be noted that, in the case of top-down models, this decision is not relevant as the model would, by definition, be associated with the real operator whose financial accounts are used.

[13] In some cases, more than one "hypothetical existing operator" can be modelled (e.g. one with similar characteristics to the incumbent and one representing the alternative operators).

In the event that operators[14] in the country are using different technologies, the NRA should also take a decision on the technology used by the reference operator. In these cases, it is more common to build different models and define different prices based on the technology (especially in the case of fixed access). However, some NRAs have an obligation to set technology-neutral tariffs and need to take a decision on a reference operator that either ensures cost recovery for all operators or is compatible with the most cost-effective technology.

## 2.7 Services and increments

### 2.7.1 List of services considered in the model

When developing a cost model, it is important to decide on those services about which the NRA needs information. The answer, generally, is to include those wholesale services that are regulated. It is important, however, to include all other services that are material enough to affect the operator's economies of scale and scope of activity. For example, it is essential to also include demand associated with retail services[15] in order to ensure that the size of the modelled operator is sufficiently representative of real operators.

The second decision concerns the granularity of the model. The models should allow for accurate dimensioning of the networks and their costs, while avoiding unnecessary complexity. Specifically, services should be considered individually in the model on the basis of the following criteria:

- **Materiality**: Services representing a significant number of connections or amount of traffic should be incorporated in the model.
- **Technical singularity**: Services whose provision would lead to technical differences in the use of network resources should be treated separately.
- **Relevance**: Services that, despite their low materiality, are crucial for regulation as they represent a key input for other operators.

It is important to highlight that the disaggregation of services by technology is justified only if the regulated charges are expected to differ between technologies (e.g. copper versus fibre access). Otherwise, it is more appropriate to avoid disaggregation at the service level, even if the traffic mix by technology is actually taken into account in the network dimensioning.

### 2.7.2 Definition of the increments

As described above, the calculation of incremental costs is associated with the savings that could be achieved if a service that is part of a group of services was not provided. Even if incremental costs could, in theory, be calculated for each service, the economies of scale of telecommunication networks and the large capacity of network equipment mean that such an approach would lead to very small or even zero incremental costs. Therefore, the most common practice for the calculation of incremental costs is to group services into so-called "increments".

[14] For which regulated tariffs should be defined.
[15] It should be noted that this may not require the inclusion of retail costs.

A decision therefore needs to be taken on how such increments are to be defined. Three main approaches have been identified for the definition of increments:

- **Based on technology**: Services are grouped into increments according to their technology (i.e. GSM, UMTS, LTE). This approach is more commonly used by operators for supporting profitability systems and pricing (estimation of variable costs).
- **Based on service type**: Increments are defined for each of the main groups of services (for example subscription, voice, data and other services). This approach is more common among NRAs, as the main concern is to identify those costs that are directly attributable to certain services. There are some peculiarities associated with the implementation of this approach depending on the type of network modelled:
    - In the case of mobile networks, this approach usually results in the separation of data services from other services (e.g. voice, SMS). In some countries, messaging services are separated from voice services.
    - In the case of fixed networks, the most common approach is to separate access services from conveyance services. It is important to note, however, that if common and joint network costs are allocated based on effective capacity (see the section on cost standard above), cost elements are clearly associated with each increment and a single increment could be defined.
- **Based on a wholesale/retail distinction**: Increments are defined as groups of retail or wholesale services. This is, for instance, the approach proposed by the European Commission,[16] which specifies that voice interconnection services should be defined as the relevant increment for the determination of pure incremental costs.

## 2.8 Network topology design

The topology of the network to be designed is determined mainly by the locations of the nodes. There are three common approaches used for network topology design in bottom-up models:[17]

- **Scorched node**: This uses the location of existing network nodes. It should be noted that that the estimated equipment in each node is calculated based on demand and other parameters. This approach is relatively simple to implement but it may include potential inefficiencies in operators' networks and does not allow for the modelling of a hypothetical operator with a different footprint to that of the existing operator.
- **Modified scorched node**: This is a variant of the scorched-node approach. Under this approach, the location of network nodes does not correspond strictly to operators' networks but is based on their existing nodes. Locations may be modified if any inefficiency is identified or if a hypothetical operator with a different footprint is to be considered. This approach is about as complex as the previous one to implement, but it allows for the removal of some inefficiencies.
- **Scorched earth**: This approach estimates the locations of an optimized network without the restrictions of the existing network. It also allows for the calculation of a theoretical network, without relying on existing networks. However, this option is significantly more complex to implement.

In practical terms, the scorched-earth approach is generally preferred in the case of mobile access networks and certain fixed access networks. Core and backbone networks are more difficult to implement based on the scorched-earth approach since the locations can depend

[16] EU. EUR-Lex. Commission Recommendation of 7 May 2009 on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU. (op. cit.)

[17] It should be noted that top-down models do not require a decision on network topology design, since they are based on the financial accounts of the operators.

on exogenous factors (such as regional distribution, existence of previous facilities, etc.). They are therefore most typically modelled on the basis of a scorched-node or modified scorched-node approach.

## 2.9 Geographical modelling

The design of access networks is highly dependent on the geographical, topographical and demographic characteristics of the zones to be covered. In order to correctly reflect such characteristics in a bottom-up model,[18] geotypes that group areas with similar characteristics are very commonly defined. The definition of the geotypes depends on the type of network and on the specificities of the country. The main cost drivers that should be taken into account for the definition of geotypes are (at least):

- For mobile networks:
  - Population and population density, as they can provide a good indication of traffic consumption.
  - Population centres per $km^2$ could be required in order to recognize the specificities of areas where population density may be low but where the population is mostly concentrated in few scattered locations.
  - Topography. This characteristic is crucial to properly reflect mobile networks' coverage, which is significantly reduced in mountainous areas.
  - Seasonality. In some countries, defining rural areas that are a destination for seasonal tourism[19] as a specific geotype can improve the accuracy of network dimensioning.
- For fixed networks:
  - Building density is the main driver of civil infrastructure costs, which constitute the largest part of fixed access network costs.
  - Households and/or businesses per building, which share the same civil infrastructure costs, although they require certain additional in-building infrastructure.

[18] It should be noted that top-down models do not require geographical modelling, since they are based on the financial accounts of the operators.
[19] May require additional capacity that could be underused in the rest of the year.

# 3 Main phases of the implementation of a cost model

The implementation of a cost model is a long and complex process that should be carefully planned and organized. This section provides guidance to NRAs on the typical phases that should be followed for the successful implementation of a bottom-up or top-down cost model.

## 3.1 Main phases of the implementation of a bottom-up cost model

As described above, bottom-up models for regulatory purposes are typically developed by NRAs. Accordingly, NRAs should lead such initiatives and carefully plan all the phases thereof.

Despite being led by NRAs, the implementation of a bottom-up model typically requires a mid-to-high level of involvement from telecommunication operators; the operators are an excellent source of information and verification that can enrich the cost-modelling exercise. However, reasonably accurate bottom-up cost models can be developed without the support of operators (e.g. if they decline to collaborate) as long as the regulator has enough information in-house (e.g. service demand) and access to international benchmarks[20] (e.g. for network equipment unit costs).

The main phases involved in the implementation of a bottom-up cost model are described below:


- **Kick-off**: A bottom-up implementation initiative should start with:
  - An internal kick-off meeting to involve other departments within the NRA that may need to use the model or can provide relevant information to populate it.
  - An external kick-off meeting with operators, to inform them about the objectives of the initiative and the stages in which the NRA expects to involve them (e.g. data collection, consultation). Kick-off meetings with operators help to increase the transparency of the initiative, while allowing operators to participate actively in the development of the model and organize their resources according to the initiative's needs.
- **Methodology design**: This phase defines, at least, all the key methodological elements described in the previous section that will clearly establish the basis for the implementation of the bottom-up cost model. It is highly advisable to separate this phase from the actual implementation of the model so as to ensure that discussions are not influenced by the quantitative impact of each methodological element on the final results.

  Main deliverable: The methodology document[21] for the model.
- **Consultation on the methodology**: It is advisable to hold a specific consultation process on the methodology to allow the NRA and operators to provide their views on the criteria that will shape the design of the model. In line with the indications provided regarding the previous phase, separating this phase from the consultation on the model allows

[20] One reference document for benchmarking is the ITU Practical Guide on Benchmarking Telecommunication Prices. Geneva, 2014.

[21] Some examples: Belgium, Denmark, Mexico [in Spanish], Oman.

NRAs to focus the discussions on the methodological framework and helps to enhance the efficiency of the process (any decision to change the methodology could mean that significant efforts are needed to redesign the model). Some NRAs skip this phase to reduce the overall implementation time for the model.

Main deliverables: Consultation document and position statement assessing feedback received.[22]

- **Data collection**: Bottom-up models are data intensive and a reasonable amount of the information required should be expected to come from operators (even if a hypothetical operator is modelled, the operators may be the best information source for certain data items). It is important to issue clear data request forms, with thorough supporting documentation with a view to striking an optimal balance between data requirements and the time available to provide the information. In designing such forms, it is advisable to:
  - ensure that operators are not requested to provide information already available within the NRA;
  - provide detailed descriptions of the data fields requested;
  - outline the reporting units and periods.

  To further increase the chances of this phase succeeding, it is recommended to hold meetings or workshops with the operators in order to clarify any potential questions about the request.

  Ideally, data-collection processes should be launched once the methodology is established. However, some NRAs undertake this phase beforehand to minimize the time-frame of the initiative, recognizing that the requests made are not likely to vary based on the final methodological framework adopted.

  Main deliverable: Data request forms and supporting documentation.
- **Data validation**: The outputs of a cost model are heavily reliant on inputs. Therefore, in the interests of accuracy, it is essential to validate the quality of the information gathered, which will eventually form part of the model's inputs. Cross-checking the information obtained with external sources (e.g. benchmarks) can help to identify potential mistakes or misunderstandings. Time should be provided for interaction with operators to understand, clarify and correct the information originally reported.
- **Cost-model development**: This phase comprises the development of the model itself, its population as well as validation of the results using the information available (e.g. number of sites, cost base). This validation activity is sometimes referred to as a calibration or reconciliation exercise.

  Main deliverables: Cost model and supporting documentation.[23]
- **Consultation on the model**: In this phase, feedback is gathered from stakeholders on the model's inputs, technical and economic algorithms and outputs. The responses received allow NRAs to ensure that the model is working properly and duly reflects the operational and financial realities faced by the national operators.

  Ideally, the model should be shared with stakeholders (either through a closed process with operators only or publicly announced on the NRA's webpage) so that they have access to its inputs, algorithms and outputs. In such cases, NRAs should pay due regard to the confidentiality of the information to avoid disclosing any sensitive data. To that end, confidential information can be anonymized (e.g. by randomly adjusting the figures within a reasonable range). It is recommended that NRAs avoid replacing confidential information with unrepresentative figures as this is likely to hamper stakeholders' ability to provide meaningful comments.

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22 Some examples: Belgium, Cyprus, Denmark, Mexico [in Spanish], Oman (consultation document and position statement).

23 Some examples: Belgium (model and manual), European Commission (mobile model and fixed model), Denmark (manual), Mexico [in Spanish].

Main deliverable: Consultation document and position statement assessing feedback received.[24]

- **Price decision**: Based on the feedback received from the consultation on the model, NRAs are expected to introduce some final modifications (if required) to the cost model and close it. Based on this final version of the model, NRAs will need to take pricing decisions on the services for which the model was developed. Although some NRAs are obliged by law to set the regulated charges directly based on the results of a cost model, the most common practice involves consideration of additional inputs (e.g. results of top-down cost models, market data, international benchmarks) when setting the regulated tariffs.

  Main deliverable: Price decision.[25]

## 3.2 Main phases of the implementation of a top-down cost model

In contrast to the implementation of a bottom-up cost model, top-down regulatory cost models[26] should be developed by operators, as the amount of information and granularity required make the task unfeasible for NRAs. However, it is essential that NRAs clearly define the methodology to be applied, the implementation period and phases, and set up a well-structured audit/review procedure to ensure that the results obtained are fully representative.

The main phases involved in the implementation of a top-down cost model are described below:


- **Definition of the regulatory framework**: The implementation of a top-down regulatory cost model should be driven by the needs of NRAs to access certain information. It is therefore important for NRAs to determine the features of the desired model so that it is fit for purpose. NRAs should define the main methodological characteristics and the reports and manuals to be provided by the operators. For example, it is highly advisable to define clearly the minimum granularity (e.g. minimum set of accounts) to be included at each stage/level of the model. Otherwise, NRAs may not have the transparency necessary to understand the allocation processes and ensure that the methodological principles established are properly followed. This aspect takes on even greater importance if more than one operator has to submit top-down cost-accounting information so as to ensure comparability among operators.

  Main deliverable: Regulatory framework.[27]
- **Development of the implementation manual**: Before the development of the top-down cost model itself (which requires a significant amount of time and effort), NRAs are advised to request operators to draw up an implementation manual describing how they expect to fulfil the requirements and methodologies defined in the regulatory framework. During this phase, NRAs may identify in advance some inconsistencies with the approved guidelines and request operators to resolve them before they kick-off the implementation of the

[24] Example: Oman.
[25] Some examples: Paraguay, Spain [in Spanish].
[26] Some operators use top-down cost models for their internal activities, such as profitability monitoring, tariff design, etc.
[27] Some examples: Colombia [in Spanish], Mexico, Oman, Saudi Arabia (Regulatory Framework [in Arabic] and Guidelines).

model. Ideally, the implementation manual should be subject to approval by the NRA before operators are given the green light to proceed with the development of the model.

Main deliverable: Implementation manual.[28]

- **Implementation of the cost model**: Once the implementation manual is approved, operators should implement the model itself. This phase is the one that requires the most time and effort in the entire initiative. When first implemented, some support from NRAs may help to promote smooth implementation and avoid delays. When the model is subsequently implemented, this support from NRAs is generally no longer necessary.

  Main deliverable: Cost model and results.[29]

- **Audit/review**: Top-down models are generally reported annually, some months after the financial accounts are audited. The results of the model should be audited/reviewed to ensure that they are accurate, comply with the regulatory framework and do not contain errors. This audit/review can be carried out either by the operator itself (e.g. through its auditor) and/or by the NRA (e.g. through an independent entity); the latter option is recommended as it gives NRAs further control over the audit activities to be performed and the areas of focus to be reviewed.

  Main deliverables: Audit/review report and resolution approving the results.[30]

[28] Example: Mexico [in Spanish].
[29] The model and results are not generally made public, although some examples can be found United Kingdom .
[30] Some examples: Spain (Resolution and Revision Report) [both in Spanish].

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