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Report for ANACOM

Conceptual approach for the fixed BU-LRIC model

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Contents

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1 Introduction

Autoridade Nacional de Comunicações (ANACOM) has commissioned Analysys Mason Limited (Analysys Mason) to update the bottom-up long-run incremental cost (BU-LRIC) model for the purpose of understanding the costs of fixed voice termination services in Portugal, a model which Analysys Mason itself developed between 2013 and 2015 (‘the 2014 model’). This wholesale service falls under the designation of Market 1[1] (previously Market 3, according to the 2009 European Commission Recommendation on relevant markets).

The model developed has been used by ANACOM to inform its market analysis for fixed termination. The process in place for the development of the BU-LRIC model includes a consultation, which gives industry participants the opportunity to contribute at various points during the project.

Modelling approach

In May 2009, the European Commission (the EC, or the Commission) published its Recommendation on the regulatory treatment of fixed and mobile termination rates in the European Union (EU) (‘the Recommendation’).[2] The Recommendation adopts a more specific approach to costing and regulation than previous guidelines. It recommends that National Regulatory Authorities (NRAs) calculate the costs of termination services on the basis of ‘pure BU-LRIC models’. In particular, the Recommendation sets out the following guidelines:

- the relevant increment is the wholesale call termination service only (as opposed to all traffic as in total service long-run incremental cost (TS-LRIC) or long-run average incremental cost plus (LRAIC+) models)
- common costs and mark-ups are excluded.

The 2014 model developed by ANACOM followed the EC’s ‘pure LRIC’ Recommendation. The 2017 model has been updated, maintaining the same methodology.

This consultation paper describes the modelling approach used in order to implement the EC Recommendation; therefore, in the remainder of this document we present all the modelling principles proposed for ANACOM’s bottom-up pure LRIC model, taking into account the following:

- the Recommendation has left some room for further debate on the precise implementation

1 Commission of The European Communities, *COMMISSION RECOMMENDATION of 9.10.2014 on relevant product and service markets within the electronic communications sector susceptible to* ex ante *regulation*, 9 October 2014.

2 COMMISSION RECOMMENDATION of 7 May 2009 on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU (2009/396/EC). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:124:0067:0074:EN:PDF

- an older version of this document was put up for public consultation by ANACOM during the 2014 consultation process
- the new version of the documentation and model include updated demand forecasts, network parameters and cost inputs.

The conceptual issues to be addressed throughout this document are classified in terms of four dimensions: operator, technology, service and implementation, as shown in Figure 1.1 below.

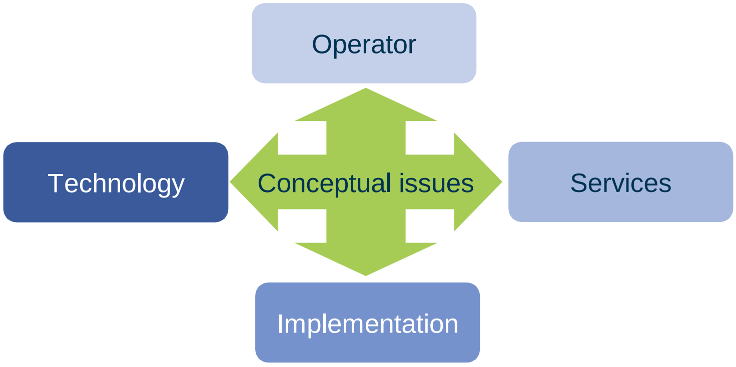

Figure 1.1: Framework for classifying conceptual issues [Source: Analysys Mason, 2018]

Operator The characteristics of the operator used as the basis for the model represent a significant conceptual decision with major costing implications:

- What **structural implementation** of the model should be applied? Typically, this question aims to resolve whether top-down models built from operator accounts should be used, or whether a more transparent bottom-up network design model should be applied. This issue is not debated further herein as ANACOM requires that a bottom-up approach be applied to calculate the costs of fixed voice termination.
- What **type of operator** should be modelled – actual operators, average operators, a hypothetical existing operator, or some kind of hypothetical entrant to the market?
- What is the **footprint** of the operator being modelled – is the modelled operator required to provide national service (or at least to 99%+ of the population), or some specified sub-national coverage?
- What is the **scale** of the operator in terms of market share?

Technology The type of network to be modelled depends on the following conceptual choices:

- What **technology and network architecture** should be deployed in the modelled networks? This concept encompasses a wide range of

technological issues which aim to define the modern and efficient standard for delivering the voice termination services.

- What is the appropriate way to define the **network nodes**? When building models of operator networks in a bottom-up manner using modern technology, it is necessary to determine which functionality should exist at the various layers of nodes in the network. Here we can use either a *scorched-node* or a *scorched-earth* approach, although more complex node adjustments may be carried out in the fixed network.

Service

Within the service dimension, we define the scope of the services being examined:

- What **service set** does the modelled operator support?
- How should **traffic volumes** be determined?
- Are costs calculated at the **wholesale** or **retail** level?

Implementation

A number of implementation issues must be defined to produce a final cost model result. They are:

- What **increments** should be costed?
- What **depreciation** method should be applied to annual expenditures?
- What is the **weighted average cost of capital** (WACC) for the modelled operator?

Structure of the document

The remainder of this document is structured as follows:

- Section 2 introduces the principles of LRIC
- Section 3 deals with operator-specific issues
- Section 4 discusses technology-related conceptual issues
- Section 5 examines service-related issues
- Section 6 explores implementation-related issues.

The report includes several annexes containing the following supplementary materials:

- Annex A introduces aspects of the implementation of the economic depreciation
- Annex B includes a list of the fixed core next-generation network (NGN) assets
- Annex C includes a list of acronyms used throughout this document.

2 Principles of long-run incremental costing

This section discusses the main concepts and principles underlying the long-run incremental costing methodology for fixed voice termination. It is structured as follows:

- concepts of competitiveness and contestability (Section 2.1)
- long-run costing (Section 2.2)
- incremental costing (Section 2.3)
- efficiently incurred costs (Section 2.4)
- costs of supply using modern technology (Section 2.5).

2.1 Competitiveness and contestability

The 13th Recital[3] of the EC Recommendation is in line with the principle that LRIC reflects the level of costs that would occur in a competitive or contestable market. Competition ensures that operators achieve a normal profit and normal return over the lifetime of their investment (i.e. the long run). Contestability ensures existing providers charge prices that reflect the costs of supply in a market that can be entered by new players using modern technology. Both of these market criteria ensure that inefficiently incurred costs are not recoverable.

2.2 Long-run costs

Costs are incurred in an operator's business in response to the existence of, or change in, service demand, captured by the various cost drivers. Long-run costs include all the costs that will ever be incurred in supporting the relevant service demand, including the ongoing replacement of assets used. As such, the duration 'long run' can be considered at least as long as the network asset with the longest lifetime. Long-run costing also means that the size of the network deployed is reasonably matched to the level of demand it supports, and any over- or under-provisioning would be levelled out in the long run.

Consideration of costs over the long run can be seen to result in a reliable and inclusive representation of cost, since all the cost elements would be included for the service demand supported over the long-run duration, and averaged over time in some way. On the other hand, short-run costs are those which are incurred at the time of the service output, and are typically characterised by large variations: for example, at a particular point in time, the launch or increase in a service demand may cause the installation of a new capacity unit, giving rise to a high short-run unit cost, which then declines as the capacity unit becomes better utilised with growing demand.

Therefore, in a LRIC method, it is necessary to identify incremental costs as all cost elements, which are incurred over the long run to support the service demand of the increment.

3 L 124/69 of the Official Journal of the European Union (20 May 2009).

This is in agreement with the 13th Recital of the EC Recommendation, which recognises that all costs may vary over the long run.

2.3 Incremental costs

Incremental costs are incurred in the support of the increment of demand, assuming that other increments of demand remain unchanged. Put another way, the incremental cost can also be calculated as the avoidable costs of not supporting the increment.

There is considerable flexibility in the definition of the increment, or increments, to apply in a costing model, and the choice should be suitable for the specific application. Possible increment definitions include:

- the marginal unit of demand for a service
- the total demand for a service (e.g. voice service termination, which is the option favoured by the EC Recommendation)
- the total demand for a group of services
- the total demand for all services in aggregate.

In Figure 2.1, we illustrate where the possible increment definitions interact with the costs that are incurred in a five-service business.

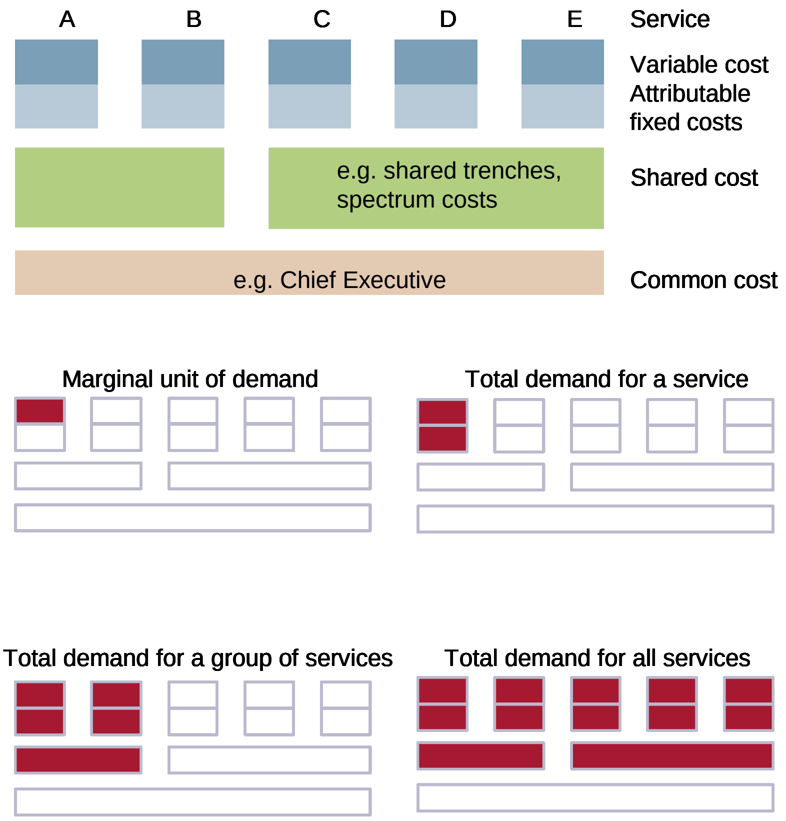

Figure 2.1: Possible increment definitions [Source: Analysys Mason, 2018]

Section 6.1 discusses the definition of the increments that are proposed to be used in the BU-LRIC model in more detail.

2.4 Efficiently incurred costs

In order to set the correct investment and operational incentives for regulated operators, it is necessary to allow only efficiently incurred expenditures in cost-based regulated prices. The specific application of this principle to a set of cost models depends significantly on a range of aspects:

- detail and comparability of information provided by individual operators
- detail of modelling performed
- the ability to uniquely identify inefficient expenditures
- the stringency in the benchmark of efficiency which is being applied[4]
- whether efficiency can be distinguished from below-standard quality.

The Portuguese operators are active in a competitive market, which includes both the competitive supply of services to end users, and the competitive supply of infrastructure and services to those operators. Therefore, the *a priori* expectation of inefficiencies in the market may be limited. However, it is still necessary to ensure that there is a robust assessment of efficiently incurred costs.

4 For example: most efficient in Portugal, most efficient in Europe, most efficient in the world.

2.5 Costs of supply using modern technology

In a market, a new entrant that competes for the supply of a service would deploy modern technology to meet its needs – since this should be the efficient network choice. This implies four 'modern' aspects: (i) the choice of network technology (e.g. TDM, IP); (ii) the capacity of the equipment; (iii) the price of purchasing that capacity; (iv) and the costs of operating and maintaining the equipment. Therefore, a LRIC model should be capable of capturing these aspects:

- *The choice of technology should be efficient* – Legacy technologies which are being phased out should not be considered modern.
- *Equipment capacity should reflect the modern standard* – For instance, switches become larger in absolute capacity over time; new-generation switches may be optimised to have improved capacity.
- *The modern price for equipment represents the price at which the modern asset can be purchased over time* – It should represent the outcome of a reasonably competitive tender for a typical supply contract in Portugal. It is expected that operators in Portugal should be able to acquire their equipment at typical European prices, and that they should have a comparable purchasing power to that of their European peers. A data request has been sent to the Portuguese fixed operators in order to obtain their estimate of the unit costs for the different network elements. We complemented the Portuguese data points with European benchmarks in order to come to a final view of the equipment costs in the model.
- *Operation and maintenance costs should correspond to the modern standard of equipment*, and represent all the various facility, hardware and software maintenance costs relevant to the efficient operation of a modern standard network.

The definition of modern equipment is a complex issue. Fixed operators around the world are at different stages of deploying fixed next-generation IP-based core networks: from initial plans to fully deployed.

The EC Recommendation states that for a fixed network the efficient technological choice on which the cost models should be based in principle is a next-generation-based core network. This appears to be the current efficient technology applicable to Portugal. (Please see Section 4.1 for a discussion about the choice of network architecture for the BU-LRIC model.)

3 Operator issues

This section discusses the following aspects of the modelled operator:

- type of operator (Section 3.1)
- network footprint of the operator (Section 3.2)
- efficient scale of the operator (Section 3.3).

3.1 Type of operator

The type of operator to be designed in the model is the primary conceptual issue which determines the subsequent structure and parameters of the model. It is also important because of the need to ensure consistency between the choice of operator in the fixed termination model and subsequent cost-based regulation of real players.

The full range of operator choices is:

- **Actual operators**: in which the costs of all actual market players are calculated.
- **Average operator**: in which the players in the fixed market are averaged together to define a 'typical' operator.
- **Hypothetical existing operator**: in which an operator is defined with characteristics similar to, or derived from, the actual operators in the market, except for specific hypothetical aspects that are adjusted (e.g. the date of entry).
- **Hypothetical new entrant**: in which a hypothetical new entrant to the market is defined as an operator which enters the market with today's modern network architecture, and acquires an incumbent's share of the market.

At this stage, we exclude the option to apply actual operators. This is because:

- It would reduce costing and pricing transparency and increase the risk/complexity of ensuring identical/consistent principles are applied if the method were to be applied to individual operator models for all fixed players.
- The EC recommends costing an operator with an efficient scale – by implication, not an actual operator.
- It would be inconsistent with the previous mobile BU-LRIC approach, which adopted a hypothetical operator launching services in 2006 and reached a minimum efficient scale in 2010.

Therefore, we consider three options for the type of operator to be modelled. The characteristics of these options are outlined in the table below.

Figure 3.1: Operator choices [Source: Analysys Mason, 2018]

Characteristics	Option 1: Average operator	Option 2: Hypothetical existing operator	Option 3: Hypothetical new entrant
Date of entry	Different for all operators, therefore an average date of entry is not meaningful	Can be set to a consistent date of entry, taking account of key milestones in the real networks (e.g. migration from next-generation SDH to Ethernet)	In this case, the date of entry is inferred from the EC Recommendation, which sets a relation between time and the acquisition of market share
Technology	Different for all fixed operators (e.g. level of roll-out of all IP core), therefore an average fixed technology is not appropriate, most advanced operators would bear the costs of less-efficient ones (see 'efficiency' section below)	The technology of a hypothetical operator can be specifically defined, taking into account relevant technology components of existing networks. In the case where the hypothetical existing operator is modelled as an operator entering the market in recent years, the EC Recommendation specifies the appropriate technology mix	By definition, a hypothetical new entrant would employ today's modern technology choice. The EC specifies a next-generation all-IP fixed core network
Evolution and migration to modern technology	The main fixed operators have evolved and migrated in significantly different ways – the average evolution is not straightforward to define	The evolution and migration of a hypothetical operator can be specifically defined, taking into account the existing networks. Legacy network deployments can be ignored if migration to next-generation technology is expected in the short-to-medium term or has already been observed in real networks	By definition, a hypothetical new entrant would start with the modern technology. Therefore evolutionary or migratory aspects are not relevant. However, the rate of network roll-out and subscriber evolution are key inputs into the model
Efficiency	May include inefficient costs through the average	Efficient aspects can be defined. If modelled as a new operator that entered the market in recent years, efficient choices can be made throughout the model	Efficient choices can be made throughout the model
Comparability and transparency of bottom-up network modelling with real operators	The network model of an average operator would only be comparable with an average across the real network operators. However, it would be possible to illustrate this average comparison in a	In order to compare a hypothetical operator network model with real operators, it would be necessary to transform the actual operator information in some way (e.g. averaging, or re-scaling to reflect the characteristics of the	In principle, the hypothetical new entrant approach is fully transparent in design. However, since none of the real operators is a new entrant, it would not be possible to do a like-for-like comparison

Characteristics	Option 1: Average operator	Option 2: Hypothetical existing operator	Option 3: Hypothetical new entrant
	reasonably transparent way	hypothetical operator). While the hypothetical operator model would be transparent to industry parties, the comparison against real operator information might include additional steps which need to be explained	against real operator network information
Practicality of reconciliation with top-down accounting data	It is not possible to directly compare an average operator with actual top-down accounts. Only indirect comparison (e.g. overall expenditure levels and opex mark-ups) is possible	It is not possible to directly compare a hypothetical existing operator with actual top-down accounts. Only indirect comparison (e.g. overall expenditure levels and opex mark-ups) is possible	It is not possible to directly or indirectly compare a hypothetical new entrant model to real top-down accounts without additional transformations in the top-down domain (e.g. current cost revaluation)

There are four key issues in deciding the type of operator to be modelled:

Is the choice appropriate for setting cost-based regulation?

All three options presented above could be considered a reasonable basis on which to set cost-based regulation of wholesale fixed termination services. However in the case of Option 1, inefficient costs would need to be excluded.

What modifications and transformations are necessary to adapt real information to the modelled case?

The table above summarises the various transformations which will be required in the modelling approach (e.g. migration from next-generation SDH to Ethernet).

Are there guidelines which should be accommodated (e.g. the EC Recommendation)?

The EC Recommendation suggests that an efficient-scale operator should be modelled. However, the precise characteristics of this type of operator are not defined. In principle, all three of the above options can satisfy the efficient-scale requirement.

What flexibility does the model offer in terms of options?

A model constructed for Option 3 would be designed in such a way as to exclude historical technology migrations. It would also be mechanically designed to start its costing calculations in the year the new entrant enters the market. Therefore, the model for Option 3 can be considered linked to the type of operator modelled.

A model constructed for Option 2 can, if known at the outset, also be used to calculate costs for Option 3 by assuming a modern equivalent

asset (MEA) deployment from the beginning of the period of operation and adjusting the subscriber demand and take-up.

Therefore, Option 2 appears to be the most reasonable and appropriate choice. This view is also supported by the following points:

- The use of a hypothetical existing operator allows the model to be grounded in the reality of Portuguese network operations. In contrast, a hypothetical new entrant model would be more speculative and difficult to populate. As a result, it would have some disadvantages compared to the hypothetical existing operator approach, such as not reflecting real-world technology evolution in recent years

- The proposed methodology is consistent with paragraph 12 of the EC Recommendation, reflecting the level of costs for an operator characterised by reasonably efficient modern technology choices – not necessarily "*the most efficient possible technology choices which might be taken in a greenfield situation*". As the EC Recommendation notes, it is necessary to be able to identify the relevant technology choices, and we consider it reasonable at the time the new model is designed to refer to actual operators' recent activities, and to capture these in an existing operator model

- The hypothetical existing operator approach ensures consistency with the previous version of the fixed cost model, as well as with the mobile termination cost model that Analysys Mason developed and updated on behalf of ANACOM.

Proposed concept 1: We do not recommend Option 1 (average operator) as it is dominated by historical issues rather than modern and efficient network aspects. We do not recommend Option 3, as it excludes historical technology migrations and consistency with Portuguese operators.

We propose that the cost model be based on Option 2 (hypothetical existing operator) since this enables the model to determine a cost consistent with the existing suppliers of fixed termination in Portugal, such that actual network characteristics in recent years can be taken into account.

The operator modelled would therefore be:

A fixed operator rolling out a national NGN IP core network in 2009, and launching voice services in 2010. The core network design would be linked to a specific choice of next-generation access technology. The NGN IP core would be operated for the long term, at least 25 years, and thus migration off the NGN IP core would not be modelled.

3.2 Network footprint of operator

Coverage is a central aspect of network deployment. The question of what coverage to apply to the modelled operator can be understood as follows:

- What is the current level of coverage applicable to the market today?
- Is the future level of coverage different from today's level?
- Over how many years does the coverage roll-out take place?
- What quality[5] of coverage should be provided, at each point in time?

The coverage offered by an operator is a key input to the costing model. The definitions of coverage parameters have two important implications for the cost calculation:

Level of unit costs due to the present value (PV) of expenditures

The rate, extent and quality of coverage achieved over time determine the PV of associated network investments and operating costs. The degree to which these costs are incurred prior to demand materialising represents the size of the 'cost overhang'. The larger this overhang, the higher the eventual unit costs of traffic will be. The concept of a cost overhang is shown below in Figure 3.2.

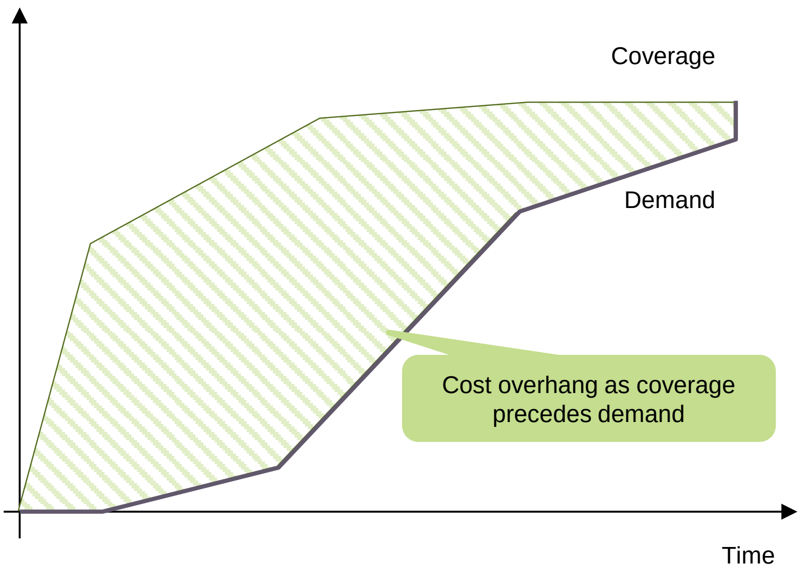

Figure 3.2: Cost overhang [Source: Analysys Mason, 2018]

Identification of network elements that are driven by traffic

In a situation where the coverage deployment is significant, fewer network elements are likely to be dependent on traffic. This has particular implications during the application of a small traffic-related increment (see Section 6.1 on *Choice of Increment*).

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5 In the case of fixed networks, the quality is related to the availability, access sharing, etc.

Using actual fixed network coverage is a pragmatic choice for the principle of fixed network footprint; PT's network coverage is national, and therefore it appears a reasonable choice. If regional coverage would lead to significant and exogenous cost differences, a case could be made for modelling regional coverage. However, cable operators are not limited by exogenous factors in expanding their coverage. They have the possibility to do so by their own deployment, leasing capacity outside their own coverage area, or by joining with other sub-national operators (as is already achieved by the main cable operators). Different cost prices due to lower economies of geographical scale are therefore not to be reflected in the costs of an efficient operator providing termination services.

Proposed concept 2: National levels of geographical coverage represented in the model will be comparable to that offered by current national fixed operators in Portugal.

3.3 Efficient scale of operator

One of the main parameters that defines the cost (per unit) of the modelled operator is its market share: it is therefore important to determine the evolution of the market share of the operator and the period over which this evolution takes place.

The parameters chosen for defining the operator's market share over time influence the overall level of economic costs calculated by the model. The quicker the operator grows,[6] the lower the eventual unit cost of traffic should be.

The scale of the modelled operator is primarily determined by the number of actual players in the fixed market. In Portugal, there are four major competing providers: MEO, Vodafone, NOS[7] and NOWO; they all use different access technologies: copper, cable and/or fibre.

Consistent with ANACOM's desire to reflect a competitive, efficient, cost-based market for the regulated supply of wholesale voice termination, the BU-LRIC model will take into account the costs of an operator in a fully competitive market:

- in a fully competitive market with *n* operators, each operator will have a *1/n* share of the market in the long term, i.e. *1/n* share of all standard retail and wholesale services in Portugal.

However, it should be noted that the main fixed operators do not cover the same areas of Portugal. For example, all of them are present in Greater Lisbon and Porto; however, some areas are only covered by MEO and the cable operators, while in others MEO is the only service provider:

- The combined network of the cable operators covers most of the households in 232 municipalities, with little overlap between the different networks. This implies that a two-player

6 E.g. the net present value of demand – therefore reflecting the discounted combination of eventual share and rate of acquiring share.

7 Following consolidation between Sonaecom and ZON Multimedia (approved in July 2013).

market in areas not covered by the fibre-to-the-home (FTTH) network of alternative operators seems reasonable.

- Both MEO and the alternative operators are building their own FTTH networks. MEO already covers about two thirds[8] of the households in Portugal with fibre, while the alternative operators have entered into agreements to roll out FTTH networks in the main cities of Portugal[9]. This implies that a three-player market in areas where both MEO and cable operators are present together with the alternative operators that have rolled out fibre seems reasonable.

Another issue related to the *scale* of the modelled operator is the time taken by the operator to achieve a steady market share. The model needs to specify the rate at which the modern network is rolled out, and the corresponding rate at which that modern network carries the volumes of the operator (up to the market share in the long term). There are a number of options in terms of modelling a hypothetical existing operator:

- **Option 1: Immediate scale** – In this option, the modelled operator immediately achieves its market share, and rolls out its network just in time to serve this demand at launch. This approach does not reflect real technology transitions.
- **Option 2: Matching the modern technology transition during the modelled years** – In this option, the utilisation of the modern technology during the specific recent years is observed for the actual networks and used to define an efficient profile for the hypothetical existing operator.
- **Option 3: Assuming a hypothetical roll-out and market share profile** – In this option, a time period to achieve a target network coverage (footprint) roll-out would be specified (e.g. three years), as well as a time period to achieve full scale (e.g. four years).
- **Option 4: Roll-out and growth based on history** – It is possible to apply roll-out and volume growth profiles which have been obtained directly from (the average of) the actual fixed operators. This approach would require looking back at networks *a long time ago*, and therefore would be complex to carry out, with numerous assumptions based on historical information.

Proposed concept 3: We suggest a long-run market share of 1/*n* for the modelled operator, with the value of 'n' defined to take into account the number of networks with a significant penetration operating in each geotype:

- In geotype 1 there are primarily three or more competing providers: MEO, the cable operators and the alternative operators that have built a FTTH network. Based on this, we suggest a long-run market share of 33% in these areas.

8 2017 Q3 results from Altice Group (owner of MEO) reported 3.9 million homes passed including 0.3 million through wholesale fibre operators vs. a nationwide target of 5.3 million by 2020

9 In October 2017, Vodafone and NOS agreed to deploy and share a fibre network expected to reach close to 2.6 million homes.

- In geotype 2 where cable operators are present, there are primarily two competing providers: MEO and the cable operators. Based on this, we suggest a long-run market share of 50% in these areas.
- In geotype 3 where cable operators are not present, there is primarily only one service provider: MEO. In addition to MEO's network, a neutral operator is rolling out a new FTTx network in these municipalities, and is expected to launch its services in 2014. Based on this, the modelled operator will have a long-run market share of 50% by 2014 in these areas.
- In geotype 4 (Portuguese islands), there are primarily two competing providers: MEO and the cable operators. Based on this, we suggest a long-run market share of 50% in these areas.

Proposed concept 4: We suggest considering Option 3, which is a time period to achieve a target network coverage (footprint) roll-out of three years and a time period to achieve full scale of four years. Coverage deployments are, in many cases, dictated by the strategic choice of the operator in order to compete and achieve a minimum market share nationwide.

4 Technology issues

This section describes the most important conceptual issues with regard to technology in the fixed BU-LRIC model. These are:

- the choice of modern network architecture (Section 4.1)
- the demarcation of networks layers (Section 4.2)
- the treatment of network nodes (Section 4.3).

4.1 Modern network architecture

The fixed BU-LRIC model will require a network architecture design based on a specific choice of modern technology. From the perspective of termination regulation, modern equivalent technologies should be reflected in this model: that is, proven and available technologies with the lowest cost expected over their lifetimes.

Fixed networks tend to comprise two layers of assets, both of which can be deployed using several technologies. These are typically referred to as the access layer and the core layer (incorporating the transmission network), although the precise boundary between the two layers is technology dependent and must be carefully defined. These layers are described below.

4.1.1 Access layer

The access layer connects end users to the network, allowing them to use fixed services. The architectural options for this layer are either copper, fibre or coax cable from the network termination point (NTP) in the end-user premises back to aggregation nodes within the network tree structure:

- a **traditional copper** architecture, with copper cable deployed back to nodes (street cabinets), and then back to exchanges
- a **cable** architecture, with coax cable deployed back to a hierarchy of fibre and metro aggregation nodes
- next-generation access (NGA) architecture using fibre cable, either through
  - **fibre-to-the-node (FTTN) VDSL**, which employs almost the same structure as traditional copper, except that fibre is deployed between the street cabinet and a smaller number of exchanges (metro core locations), with VDSL electronics installed in the cabinet
  - **fibre-to-the-home (FTTH) Gigabit passive optical network (GPON)**, which deploys fibre from the exchange in a tree structure using a hierarchy of splitters
  - **FTTH point-to-point (PTP)**, which deploys fibre from the exchange to the premises.

These options are shown below in Figure 4.1.

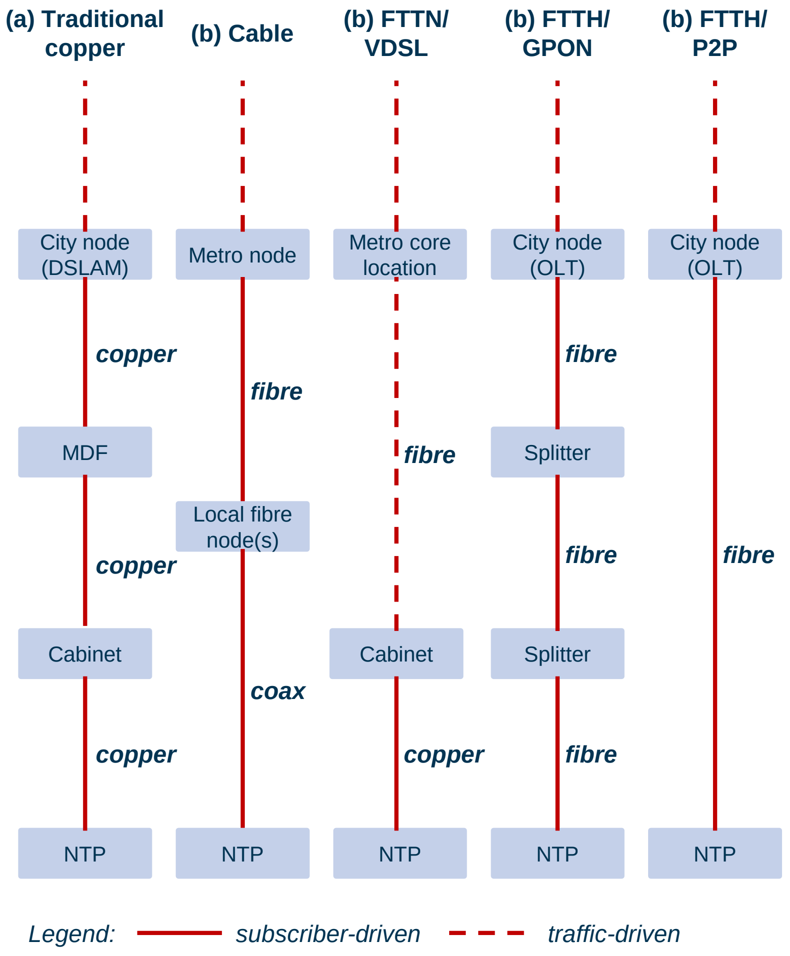


Figure 4.1: Options for the access layer in the fixed BU-LRIC model [Source: Analysys Mason, 2018][10]

As can be seen in Figure 4.1 above, there are a number of choices for the access architecture. The EC Recommendation provides no guidance on a suitable access technology for the fixed model. All five options are proven and available technologies and can be used to provide voice services: this includes cable – all the cable operators in Portugal have upgraded their networks to offer voice and high-speed broadband services. A mix of technologies may be appropriate: for example, fibre deployment in urban areas with traditional copper retained in the most remote areas of Portugal.

As the purpose of the BU-LRIC model is to understand the costs of fixed voice termination services in Portugal, we are not modelling the access network. These resources are located before the first point of traffic concentration, and, in line with the EC Recommendation, they should be excluded from the calculation of the costs of termination. However, the technology used in the access network will influence the design of the backbone and core network.

The model considers that the modern equivalent technology to provide voice services on a fixed network is voice-over-Internet-Protocol (VoIP) over a fibre access network (or at least, in most of

10 This figure has been updated according to one party's comment on Concept 8.

the network).[11] Therefore, the model considers a copper and fibre access network, without explicitly considering alternative technologies such as cable, wireless or other access technologies.

Proposed concept 5: The modelled fixed access layer will be based on copper/fibre technology. Migration from copper to fibre will be modelled taking into account the NGA roll-outs of the fixed operators in Portugal.

4.1.2 Core layer

As in the access layer, there are both traditional and NGN core architectures. An NGN core is defined as a converged IP-based platform which will carry all services on the same platform. Certain deployment options are upgrades to the public switched telephone network (PSTN), while others use transport based on Ethernet and IP/MPLS switches and routers. However, the choice of NGN control layer is heavily influenced by the access network architecture. These options are summarised below:

- Traditional **time division multiplexing (TDM) core,** where the voice and data platforms are both carried and switched separately, but are conveyed on the same transmission network.
- Cable **head-ends**, which contain several assets for distributing cable services, including:
  - antennas to receive incoming TV programming for distribution
  - a voice switch
  - the computer system and databases needed to provide Internet access, including the cable-modem termination system (CMTS).
- NGN **access gateways** (AGWs), which can be co-located in the PSTN concentrators or local switches (LS) to adapt the TDM backhaul links, retaining the separation of voice and data.
- NGN **3G digital loop carriers** (DLCs), which combine a traditional TDM cross-connect for legacy services with a broadband switch with asynchronous transfer mode (ATM) and Ethernet uplinks (i.e. voice and data can be controlled using this unit). These incorporate IP multicast capabilities for video delivery and a VoIP server gateway for PSTN emulation on a converged network. These are also commonly known as multi-service access nodes (MSANs).
- NGN **IP/Ethernet broadband access platforms** (IP BAP), which aggregate all varieties of service lines, including legacy interfaces, from IP-enabled line cards aggregated at a Gigabit Ethernet core.

The mix of access layer technologies determines the assets required in the NGN control layer. If deployments are oriented towards a copper access network, then a core with NGN DLCs would be appropriate. However, if the access layer contains extensive fibre deployments (i.e. FTTH/PTP or FTTH/GPON), then an IP BAP approach is more reasonable. The use of AGWs may be appropriate for the most remote customers, who are not assumed to be connected with fibre.

In addition, the EC Recommendation states that "*the core part could be assumed to be NGN-based*" [Clause 12]. Therefore, given that a copper/fibre access layer is deployed, we conclude that an

[11] It might be the case that in certain rural areas it could be more cost efficient to deploy a wireless network.

IP BAP architecture is most appropriate (if a cable network were to be modelled, then a cable head-end would be appropriate).

> **Proposed concept 6**: Given that a copper/fibre access layer is modelled, we will deploy an IP BAP NGN core architecture. In this architecture, traffic is transported as IP from the customer premises; voice services are enabled by applications using IP multimedia subsystems (IMS); and trunk media gateways (TGWs) are deployed at TDM interconnection points.

Please see Annex B to this document for a list of assets modelled under this architecture.

4.1.3 Transmission layer

Fixed network transmission may be accomplished by a number of alternative methods:

- ATM over SDH
- point-to-point STM microwave
- IP/MPLS over SDH
- IP/MPLS over native Ethernet.

> **Proposed concept 7**: IP/MPLS over native Ethernet seems to be the most appropriate technology. However, we understand that most Portuguese fixed operators still use SDH, at least in the access layer.

4.2 Demarcation of network layers

The EC Recommendation defines the principles for the calculation of wholesale termination rates in fixed networks, including:

> "*The default demarcation point between traffic- and non-traffic-related costs is typically where the first point of traffic concentration occurs*." [p.7]

In fixed cost models, cost recovery has historically been segregated, with:

- costs related to the access layer being predominantly subscriber-sensitive, recovered through subscription charges
- costs related to the core layer being predominantly traffic-sensitive, recovered through traffic charges.

The key concept here is that costs related to the provision of end-user 'access' should be clearly identifiable in the fixed BU-LRIC model, mainly because subscriber-driven access-related costs are excluded from the cost calculation for fixed termination services.

Fixed networks use a tree structure, as having dedicated paths between all possible combinations of end users is not feasible. As a result, traffic is concentrated as it passes up the network. The assets related to the provision of end-user *access* are those dedicated to connecting the end user to the

telecoms network, allowing it to use available services. This layer conveys traffic and does not have the capability to *concentrate it according to traffic load*. This layer of the network ends at the first asset that has this specific capability. The assets used for the provision of access are only used for the purposes of connecting end users to the network and are hence subscriber-driven. The remaining assets are driven by the traffic volumes that they concentrate.

Proposed concept 8: The demarcation point between traffic- and access-related costs will be where the first point of traffic concentration occurs, such that resources are allocated according to the offered traffic load.

In the network architecture defined above, the first traffic point of concentration is the digital subscriber line access multiplexer (DSLAM) for copper subscribers, and the optical line termination (OLT) for fibre subscribers. More specifically, the last subscriber-driven assets are the access-facing DSLAM/OLT line cards and ports, and the first traffic-driven assets are the core-facing line cards and ports of the DSLAM/OLT. The demarcation point in the network is shown below in Figure 4.2.

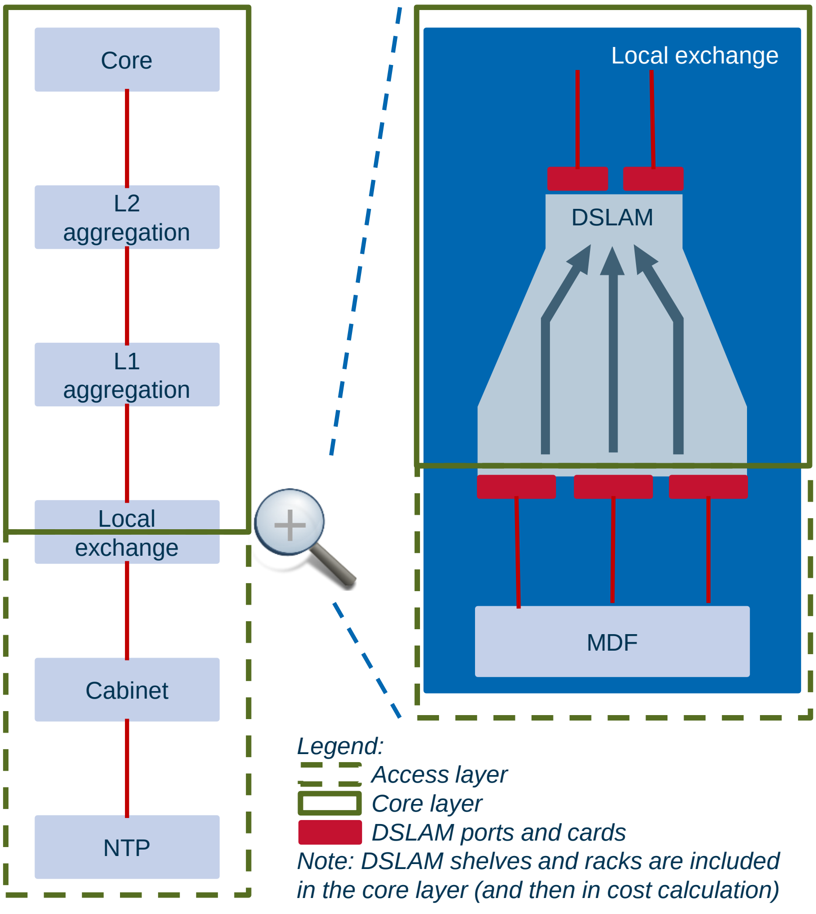


Figure 4.2: Fixed network demarcation point in a network with a copper access layer [Source: Analysys Mason, 2018]

As shown above, using this principle means that the *cost of access* for a fixed end user, where concentration first occurs at the line card in either the DSLAM or the OLT, corresponds to:

- the dedicated costs of the final drop to the end user

- a share of the costs of getting the traffic-insensitive cabling from the NTP back to the line card (trench and cabling in this link).

4.3 Network nodes

Fixed networks can be considered as series of nodes (with different functions) and links between them. In developing deployment algorithms for these nodes, it is necessary to consider whether the algorithm accurately reflects the actual number of nodes deployed. The model may be allowed to deviate from the operators' actual number of nodes in the situation where the operators' network is not viewed as efficient or modern in design.

Specification of the degree of network efficiency is an important costing issue. When modelling an efficient network using a bottom-up approach, there are several options available as to the level of detail used from actual networks. The greater the level of granularity/detail that is used directly in the calculation, the lower the extent of network 'scorching' that is being used.

Actual network — This approach implements the exact deployment of the real operator without any adjustment to the number, location or performance of network nodes.

Scorched-node approach — This assumes that the historical locations of the actual network node buildings are fixed, and that the operator can choose the best technology to configure the network at and in between these nodes to meet the optimised demand of a forward-looking efficient operator. For example, this could mean the replacement of legacy equipment with best-in-service equipment.

The scorched-node approach, therefore, determines the efficient cost of a network that provides the same services as the incumbent network, taking as given the current location and function of the incumbent's nodes.

Modified scorched-node approach — The scorched-node principle can be reasonably modified in order to replicate a more efficient network topology than is currently in place. Consequently, this approach takes the existing topology and eliminates inefficiencies. In particular, using this principle can mean:

- simplifying the switching hierarchy (e.g. reducing the number of switching nodes, or replacing a number of small switches with a larger modern switch)
- changing the functionality of a node (for instance, reducing a small exchange to the equivalent of a remote multiplexer).

Scorched-earth approach — The scorched-earth approach determines the efficient cost of a network that provides the same services as actual networks, without placing any constraints on its network configuration, such as the location of the network nodes. This approach models what an entrant would build if no network existed, based on a known location of customers and forecasts of demand for services.

This approach would give the lowest estimate of cost, because it removes all inefficiencies due to the historical development of the network, and assumes that the network can be perfectly redesigned to meet current criteria.

We propose to apply a modified version of the scorched-node principle, with the scope extended to all nodes which contain traffic-sensitive components. Therefore, the implication is that scorching will occur through all levels of traffic-concentration nodes (i.e. from local exchanges upwards to the core nodes).

We will utilise the actual node counts of the existing operators, but the functionality or capacity of the nodes may be revised, meaning the number of nodes by sub-type may change.

Proposed concept 9: We will apply a modified scorched-node principle, with scorching applied to all nodes containing traffic-sensitive assets.

5 Service issues

The primary aim of the model is to understand the costs of services related to Market 1 (fixed voice termination). However, fixed networks typically convey a wide range of services. The extent to which the modelled network can offer services to locations within its network footprint determines the treatment of economies of scope, and therefore needs to be considered. This section subsequently discusses the following aspects:

- the set of services that need to be included in the model (Section 5.1)
- the evolution of traffic volumes (Section 5.2)
- the scope of wholesale/retail costs (Section 5.3).

5.1 Service set

Economies of scope, arising from the provision of both voice and data services across a single infrastructure, will result in a lower unit cost for voice and data services. This is particularly true for NGNs, where voice and data services can be delivered via a single platform.

As a result, a full list of services must be included within the model, as a proportion of network costs will need to be allocated to these services. This also implies that both end-user and wholesale voice services will need to be modelled so that the voice platform is correctly dimensioned, costs are fully recovered from the applicable traffic volumes, and the 'pure' termination LRIC increment can be correctly modelled.

Assessing both voice and data services in the model increases the complexity of the calculation and the supporting data required. Conversely, however, excluding costs relevant to non-voice services (and developing a standalone voice cost model) can also be complex.[12]

Some of the non-voice services are proven services (particularly services like fixed broadband Internet access). However, other non-voice services, such as over-the-top (OTT) traffic, can give rise to forecast uncertainty when included in the regulated prices for voice. It will be necessary to understand the implications for voice costs of the forecast made for such uncertain non-voice services – and as a result, a range of forecast scenarios would be considered sensible to maximise understanding in such areas.

12 For example, actual top-down costs representing voice and data operation would need to be divided into standalone voice relevant costs, and additional data costs. Voice-only networks do not commonly exist in practice, meaning that the modelled network cannot be compared to any real-world operator.

Proposed concept 10: The modelled operator should provide all the non-voice services (broadband access, leased lines, IPTV, etc.) currently available (and planned) in Portugal, alongside voice services (originating and terminating voice, VoIP and transit traffic). The associated economies of scope will be shared across all services, although care ought to be taken where uncertain growth forecasts significantly influence the economic cost of voice (and therefore forecast sensitivities will be explored).

Fixed network traffic services to be modelled

The table in Figure 5.1 below shows the list of fixed services which would contribute to the deployment of the core network.

Figure 5.1: Fixed market services in Portugal [Source: Analysys Mason, 2018]

Service	Description
Local on-net calls (retail)	Voice calls between two retail subscribers of the modelled fixed operator located within the same regional node
National on-net calls (retail)	Voice calls between two retail subscribers of the modelled fixed operator that are not located within the same regional node
Non-geographic on-net calls (retail)	Voice calls from a retail subscriber of the modelled fixed operator to non-geographic numbers, including 08xx numbers, directory enquiries, and emergency services located in the network of the modelled operator
Outgoing calls to mobile (retail)	Voice calls from a retail subscriber of the modelled fixed operator to a domestic mobile operator
Outgoing calls to other fixed operators (retail)	Voice calls from a retail subscriber of the modelled fixed operator to a domestic fixed operator
Outgoing calls to international numbers (retail)	Voice calls from a retail subscriber of the modelled fixed operator to an international destination
Incoming calls to non-geographic numbers	Voice calls received from another mobile or fixed operator and terminated on a non-geographic numbers of the modelled operator
Other outgoing calls (retail)	Remaining outgoing voice calls
Local incoming calls (wholesale)	Voice calls received from another mobile or fixed operator and terminated on a retail subscriber of the modelled fixed operator, with no transit on another core node of the modelled fixed operator
Simple tandem incoming calls (wholesale)	Voice calls received from another mobile or fixed operator and terminated on a retail subscriber of the modelled fixed operator, after transiting on one core node of the modelled fixed operator
Double tandem incoming calls (wholesale)	Voice calls received from another mobile or fixed operator and terminated on a retail subscriber of the modelled fixed operator, after transiting on two core nodes of the modelled fixed operator
International incoming calls (wholesale)	Voice calls received from another international operator and terminated on a retail subscriber of the modelled fixed operator
Other incoming calls (wholesale)	Remaining incoming voice calls
Local outgoing calls (wholesale)	Voice calls originated by a wholesale subscriber of the modelled fixed operator and terminated on-net or off-net, with no transit on another core node of the modelled fixed operator

Service	Description
Simple tandem outgoing calls (wholesale)	Voice calls originated by a wholesale subscriber of the modelled fixed operator and terminated on-net or off-net, after transiting on another core node of the modelled fixed operator
Double tandem outgoing calls (wholesale)	Voice calls originated by a wholesale subscriber of the modelled fixed operator and terminated on-net or off-net, after transiting on two core nodes of the modelled fixed operator
Other outgoing calls (wholesale)	Remaining wholesale outgoing voice calls
Local outgoing calls to non-geographic numbers (wholesale)	Voice calls originated by a wholesale subscriber of the modelled fixed operator and terminated on a non-geographic number, with no transit on another core node of the modelled fixed operator
Simple tandem outgoing calls to non-geographic numbers (wholesale)	Voice calls originated by a wholesale subscriber of the modelled fixed operator and terminated on a non-geographic number, after transiting on another core node of the modelled fixed operator
Double tandem outgoing calls to non-geographic numbers (wholesale)	Voice calls originated by a wholesale subscriber of the modelled fixed operator and terminated on a non-geographic number, after transiting on two core nodes of the modelled fixed operator
Local transit calls (wholesale)	Voice calls received from another mobile or fixed operator and terminated on another mobile or fixed operator, with no transit on another core node of the modelled fixed operator
Simple transit calls (wholesale)	Voice calls received from another mobile or fixed operator and terminated on another mobile or fixed operator, after transiting on another core node of the modelled fixed operator
Double transit calls (wholesale)	Voice calls received from another mobile or fixed operator and terminated on another mobile or fixed operator, after transiting on two core nodes of the modelled fixed operator
National to International or International to National transit calls (wholesale)	Voice calls received from another international operator and terminated on another international operator, after transiting on a core node of the modelled operator

Service	Description
International transit calls (wholesale)	Voice calls received from another mobile or fixed operator and terminated on another international operator, and voice calls received from another international operator and terminated on another mobile or fixed operator after transiting on the network of the modelled operator
Other transit calls (wholesale)	Remaining transit calls
Dial-up Internet	Circuit-switched calls made by customers for Internet access
Broadband (direct access)	Provision of a broadband subscriber line (NGA or xDSL) Internet service, sold through the modelled operator's retail arm
Bitstream (indirect access)	Provision of an Internet service, resold by other operators
Leased lines	Includes leased line services provisioned for either retail customers, other operators, or internal use
TV (IPTV)	Linear broadcast television with the same channel offering for all of the TV subscribers
TV (VoD)	Broadcast television content allowing TV subscriber to select the content on demand
OTT traffic	Provision of a high-quality Internet service in order to deliver video and audio on demand

Proposed concept 11: We will model the service set included in the table in Figure 5.1 above.

5.2 Traffic volumes

In defining the modelled operator, it is necessary to define the volume and profile[13] of traffic that the operator is carrying on its network. Since the definition of the modelled operator incorporates a view of its market share, it is proposed to define traffic volumes and usage profiles for an average subscriber. This traffic profile will need to take into account the balance of traffic among the various competing services within the market. A holistic approach to forecast traffic evolution will therefore be required, for both voice and data traffic.

The volume of traffic associated with the subscribers acquired by the modelled operator is the main driver of costs in the core network, and the measure by which economies of scale will be exploited.

In the hypothetical competitive market being modelled, the subscriber base of each operator will have the same profile of usage. Therefore, the traffic profile of the modelled operator should be the market average, calculated to be consistent with the scale of that operator.[14]

Proposed concept 12: The forecast traffic profile for the modelled operator should be based on a market-average profile.

5.3 Wholesale or retail costs

The BU-LRIC model is intended to be applied in a wholesale market. As such, we intend to consider only those costs that are relevant to the provision of the wholesale network termination service.

Proposed concept 13: Only wholesale network costs will be included; retail costs will be excluded. We will consider all incremental costs that are associated with the provision of wholesale termination traffic services and that are incremental to wholesale traffic at the margin (i.e. avoidable). Common business overheads costs are not added to the cost of termination in a pure LRIC approach, because they are common costs which do not vary with the last increment of wholesale termination.

13 By 'profile', we mean proportions of calls to/from various mobile and fixed destinations, by time of day, and usage of other services.

14 E.g. the proportion of originated calls that are on-net can be expected, all other factors being equal, to be related to the size of the operator's subscriber base. Clearly, as the size of the modelled operator changes over time, a dynamically changing proportion of traffic would be estimated as on-net.

6 Implementation issues

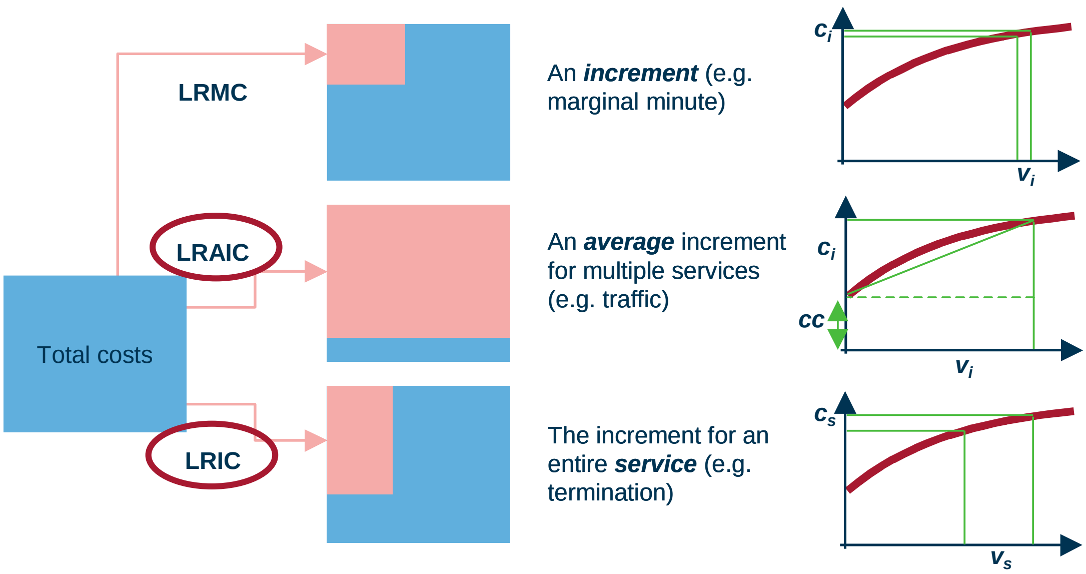
Careful consideration will need to be given to the following issues relating to the implementation of the BU-LRIC model:

- choice of service increment (Section 6.1)
- depreciation method to be applied (Section 6.2)
- WACC to be applied (Section 6.3)

6.1 Choice of increment

The LRIC of an 'increment' of demand is the difference in the total long-run cost of a network which provides all service demand including the increment, and a network which provides all service demand except the demand of the specified increment. The figure below shows three incremental cost approaches commonly used to calculate the LRIC of an increment of demand.

Figure 6.1: Increment approaches [Source: Analysys Mason, 2018]



Long-run incremental costing (LRIC, which we describe as 'pure' LRIC in the case recommended by the EC where common costs are not included) is consistent with the EC Recommendation of May 2009, which considers the increment to be all traffic associated with a single service. Based on the avoidable cost principle, incremental costs are defined as the costs avoided when not offering the service. By building a bottom-up cost model containing network design algorithms, it is possible to use the model to calculate the incremental cost: by running it *with* and *without* the increment in question, and thus determine the cost increment.

The unit cost of voice termination is then determined by dividing that cost increment by the total service volume.

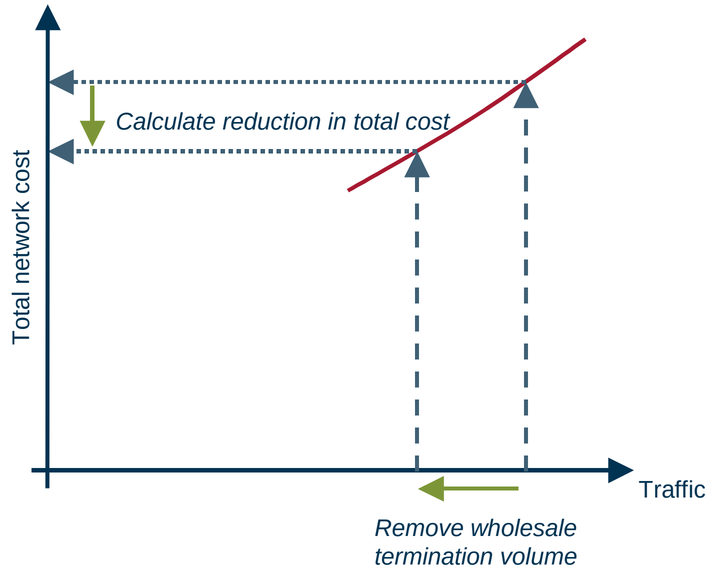


Figure 6.2: Calculation of the incremental cost of termination traffic [Source: Analysys Mason, 2018]

In the working document accompanying its Recommendation of May 2009, the EC notes (at page 14) the following: "*In practice, the majority of NRAs have implemented LRIC models which are akin to LRIC+ or a fully allocated cost (FAC) approach, resulting in an allocation of the whole of a mobile operator's cost to the different services*". The EC goes on to argue that ('pure') LRIC is a more appropriate approach for termination services.

The *pure BU-LRIC* approach will be consistent with the EC Recommendation, which specifies the following approach for the calculation of the incremental costs of the wholesale termination service:

- The relevant increment is the wholesale termination service, which includes only avoidable costs. Its costs are determined by calculating the difference between the total long-run costs of an operator providing full services and the total long-run costs of an operator providing full services except voice termination.
- Non traffic-related costs, such as subscriber-related costs, should be disregarded.
- Costs that are common and do not increase in response to voice termination traffic, such as network common costs and business overheads, should not be allocated to the wholesale terminating increment.

The colour-filled box in Figure 6.3 below indicates the costs included in the unit cost of terminated traffic for this method.

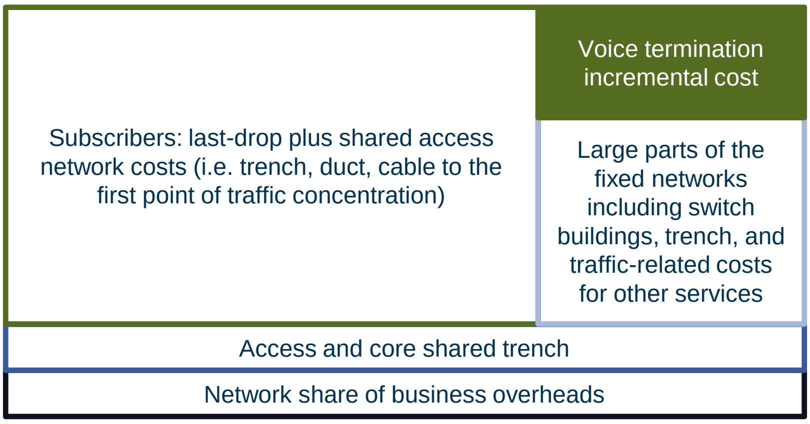


Figure 6.3: Pure BU-LRIC cost allocation [Source: Analysys Mason, 2018]

This *pure BU-LRIC* approach is consistent with the prevailing approach used for the costing of fixed voice termination in Europe, and in line with the methodology used in the mobile cost model built by ANACOM.

Proposed concept 14: The BU-LRIC model will use a pure LRIC approach, in line with the EC Recommendation. LRAIC+ costs will also be modelled for information purposes.

6.2 Depreciation method

6.2.1 Options

Before the EC Recommendation of May 2009 was published, it was possible to consider four main potential depreciation methods for defining cost recovery:

- historical cost accounting (HCA) depreciation
- current cost accounting (CCA) depreciation
- tilted annuities
- economic depreciation (ED).

Economic depreciation is the recommended approach for regulatory costing. The table in Figure 6.4 below shows that only economic depreciation considers all potentially relevant depreciation factors that should be taken into account when developing a regulatory cost model.

Figure 6.4: Factors considered by depreciation method [Source: Analysys Mason, 2018]

	HCA	CCA	Tilted annuity	ED
MEA cost today		✓	✓	✓
Forecast MEA cost			✓	✓
Output of network over time			[15]	✓

15 An approximation for output changes over time can be applied in a tilted annuity by assuming an additional output tilt factor of x% per annum.

Financial asset lifetime	✓	✓	✓	✓[16]
Economic asset lifetime			✓	✓

The primary factor in the choice of the depreciation method is whether the network output is changing over time. The situation in fixed networks is quite complicated. Historically, fixed network traffic was voice-dominated and volumes were fairly stable. In recent years, however:

- voice volumes have been falling and dial-up has almost disappeared
- broadband and other data traffic volumes are currently growing strongly.

Therefore, using tilted annuities in the fixed costing may differ significantly from economic depreciation. Furthermore, the EC recommends that economic depreciation be used wherever feasible, and this approach would be consistent with the cost recovery methodology used by ANACOM in its mobile BU-LRIC model.

Proposed concept 15: The fixed BU-LRIC model will use economic depreciation.

6.2.2 Time series

The time series, namely the period of time across which demand and asset volumes are calculated in the model, is an important input. A long time series:

- allows the consideration of all costs over time, providing the greatest clarity within the model as to the implications of adopting economic depreciation
- provides greater clarity as to the recovery of all costs incurred from services
- provides a wide range of information with which to understand how the costs of the modelled operator varies over time and in response to changes in demand or network evolution
- can also include additional forms of depreciation (such as accounting depreciation) with minimal effort.

The time series itself should be equal to the lifetime of the operator, allowing full cost recovery over the entire lifetime of the business. However, the lifetime of an operator is impractical to identify. Hence, we would propose that the time series should be at least as long as the longest asset lifetime used in the model.

Using our proxy, for a fixed BU-LRIC model, the longest-lived assets are normally set to 40 years (for trenches and ducts), so a modelling time series in excess of 40 years is often used. As a result, it may be necessary to develop a model which is capable of calculating the costs of an asset with a lifetime of 40 years at minimum.

16 Economic depreciation can use financial asset lifetimes, although strictly it should use economic lifetimes (which may be shorter, longer or equal to financial lifetimes).

Proposed concept 16: The length of the fixed BU-LRIC model time series must be at least as long as the longest asset lifetime used in the model, and a period of 45 years is suggested in order to reasonably calculate the costs of long-lived assets.

6.3 WACC

The cost model will require a cost of capital (WACC) to be specified.

The generic formula of the pre-tax WACC is $WACC_{pre-tax} = k_D * \frac{D}{D+E} + \frac{1}{1-t} * k_E * \frac{E}{D+E}$, where:

- k_D is the pre-tax cost of debt
- k_E is the post-tax cost of equity
- D is the stock of debt
- E is the stock of equity
- t is the corporate tax rate.

Moreover, we usually refer to the company gearing, defined as $G = \frac{D}{D+E}$.

While k_D is calculated/benchmarked with the typical corporate bond yields, k_E is usually calculated with the capital asset pricing model (CAPM), whose formula is $k_E = \beta * (r_M - r_f) + r_f$, where:

- β is the (de-)amplification coefficient of the spread between the average market risk and risk-free risk associated to the examined investment/share
- r_M represents the average market risk
- r_f is the market risk-free rate.

It holds the following relation between pre- and post-tax WACC: $WACC_{pre-tax} = \frac{WACC_{post-tax}}{(1-t)}$. The model will work in real terms, and then any 'nominal' WACC would need to be converted in its corresponding real one through the formula $WACC_{real} = \frac{1+WACC_{nominal}}{(1+i)} - 1$, where i is the inflation rate in a given year.

ANACOM has consulted upon the cost of capital for MEO. There are a number of documents that are of particular relevance to the BU-LRIC project:

— ANACOM's Decision regarding the methodology to be used in the determination of MEO nominal WACC[17]

— ANACOM's Decision on the value of WACC for MEO for 2017[18]:

Even if the fixed BU-LRIC model is not considering an actual operator (like MEO), we propose to use the WACC calculated by ANACOM for MEO in 2017. This ensures consistency with the

17 Available at https://www.anacom.pt/render.jsp?contentId=1184468

18 Available at https://www.anacom.pt/render.jsp?contentId=1413470

methodology used by ANACOM for calculating the cost of capital rate of MEO and to calculate the WACC for mobile operators in the mobile LRIC model developed by Analysys Mason on behalf of ANACOM.

The model will work in real, pre-tax terms (as opposed to nominal, post-tax terms, which is the convention employed for statutory financial statements).

Proposed concept 18: The model will remove the effect of inflation by expressing costs and revenues in real terms and using the corresponding 'real-terms' WACC.

Proposed concept 19: The model will simulate the effect of corporate tax by applying a 'pre-tax' WACC to pre-tax cashflows.

Proposed concept 20: The 'pre-tax' WACC will be assumed to be that already calculated by ANACOM for MEO in 2017.

Annex A Implementation of the economic depreciation

This annex describes certain key aspects and principles of the implementation of the economic depreciation. These aspects are not intended to be under consultation until the draft model has been produced. These descriptions are provided to operators to give an indication of the issues that will be dealt with during the construction of the BU-LRIC models. Operators are nonetheless welcome to provide comment on these aspects if they wish.

An economic depreciation algorithm recovers all efficiently incurred costs in an economically rational way by ensuring that the total of the revenues[19] generated across the lifetime of the business are equal to the efficiently incurred costs, including cost of capital, in present value terms: the (net) present value (NPV) of a series of (expected) future cash flows is equal to $NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t}$, where:

- CF_t is the cash flow at the instant t
- r is the discount rate (the WACC in the model).

This calculation is carried out for each individual asset class, rather than in aggregate. Therefore, asset-class specific price trends and element outputs are reflected in the components of total cost.

Present value calculation

The calculation of the cost recovered through revenues generated needs to reflect the value associated with the opportunity cost of deferring expenditure or revenue to a later period. This is accounted for by the application of a discount factor on future cash flow, which is equal to the WACC of the modelled operator.

The business is assumed to be operating in perpetuity, and investment decisions are made on this basis. This means that it is not necessary to recover specific investments within a particular time horizon (for example, the lifetime of a particular asset), but rather throughout the lifetime of the business. In the model, this situation is approximated by explicitly modelling a period of 45 years., the present value of the cash flows in the last years of the model (i.e. when the discount rate is applied) is fractional and thus any perpetuity value beyond 45 years is regarded as immaterial to the final result (it holds $\lim_{t\to\infty} \frac{1}{(1+r)^t} = 0$).

19 Strictly cost-oriented revenues, rather than actual received revenues.

Cost recovery profile

The $NPV = 0$ constraint on cost recovery can be satisfied by (an infinite) number of possible cost recovery trends. However, it would be impractical and undesirable from a regulatory pricing perspective to choose an arbitrary or highly fluctuating recovery profile[20]. Therefore, the costs incurred over the lifetime of the network are recovered in line with revenues generated by the business. The revenues generated by an asset class are a product of the demand (or output) supported by that asset class and the price per unit demand.

In the modelled environment of a competitive market, the price that will be charged per unit demand is a function of the lowest prevailing cost of supporting that unit of demand, thus the price will change in accordance with the costs of the MEA for providing the same service function[21]. The shape of the revenue line (or cost recovery profile) for each asset class is thus a product of the demand supported (or output) of the asset and the profile of replacement cost (or MEA price trend) for that asset class.

Capital and operating expenditure

The efficient expenditure of the operator comprises of all the operator's efficient cash outflows over the lifetime of the business, meaning that capital and operating expenditures are not differentiated for the purposes of cost recovery. As stated previously, the model considers costs incurred across the lifetime of the business to be recovered by revenues across the lifetime of the business. Applying this principle to the treatment of capital and operating expenditure leads to the conclusion that they should both be treated in the same way since they both contribute to supporting the revenues generated across the lifetime of the operator.

Details of implementation

The present value (PV) of the total expenditures is the amount which must be recovered by the revenue stream. The discounting of revenue in each future year reflects the fact that delaying cost recovery from one year to the next accumulates a further year of cost of capital employed. This leads to the fundamental of the economic depreciation calculation, that is:

$$PV(expenditures) = PV(revenues)$$

The **revenue** which the operator earns from the service in order to recover its expenditures plus the cost of capital employed is modelled as a function of $Output \times MEA\ price\ trend$, where:

20 For example, because it would be difficult to send efficient pricing signals to interconnecting operators and their consumers with an irrational (but $NPV = 0$) recovery profile.

21 In a competitive and contestable market, if incumbents were to charge a price in excess of that which reflected the modern equivalent asset prices for supplying the same service, then competing entry would occur and demand would migrate to the entrant which offered the cost-oriented price. The rate of demand migration is determined by the contestability of the market under consideration.

- *Output* is the service volume carried by the network element
- *MEA price trend* is the input price trend for the network element which thus proportionally determines the trend of the "revenue" that recovers the expenditures (effectively, the percentage change to the revenue tariff that would be charged to each unit of output over time).

Output is discounted because it reflects the (future) revenue stream from the network element. Any revenue recovered in the years after a network element is purchased must be discounted by an amount equal to the WACC in order that the cost of capital employed in the network element is also returned to the mobile operator.

This leads to the following general equations:

$$Revenue = \alpha \times (output \times MEA\ price\ trend)$$

$$Revenue = constant \times output \times MEA\ price\ trend$$

Using the relationship from the previous section:

$$PV(expenditures) = PV(constant \times output \times MEA\ price\ trend)$$

More specifically, since:

$$PV(expenditures) = PV(constant \times output \times MEA\ price\ trend)$$

then the *constant* is just a scalar which can be removed from the PV as follows:

$$PV(expenditures) = constant \times PV(output \times MEA\ price\ trend)$$

Rearranging:

$$constant = \frac{PV(expenditures)}{PV(output \times MEA\ price\ trend)}$$

This *constant* is thus the unit price in the first year, and the yearly access price over time is simply:

$$yearly\ access\ price\ over\ time = constant \times MEA\ price\ index$$

This yearly access price over time is calculated separately for the capital and operating components in one step in the model.

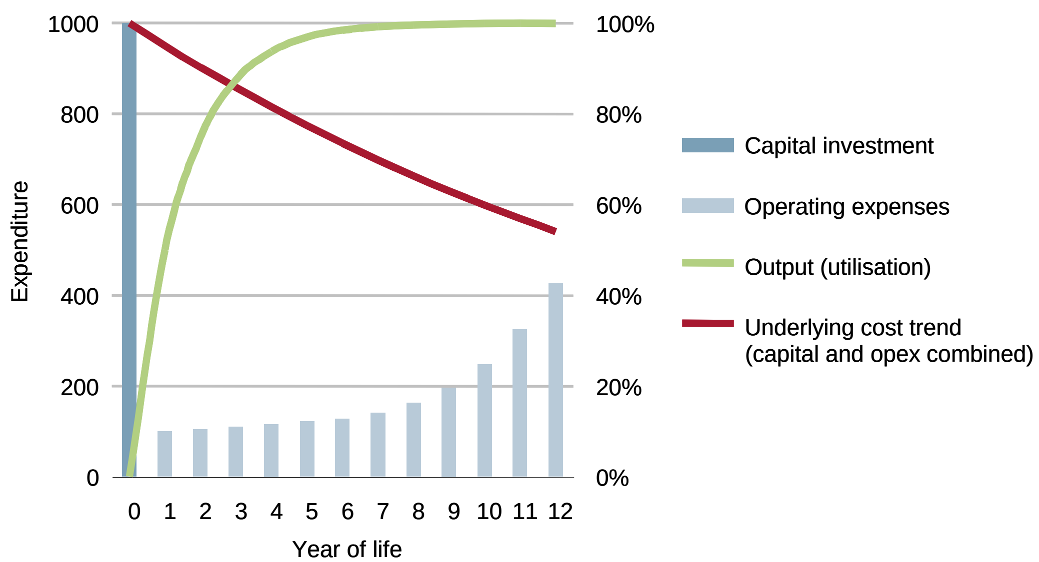
Calculating economic depreciation

The economic depreciation calculation can be expressed as: 'What time series of prices, consistent with trends in the underlying costs of production and the assumed contestability of the market, yield an expected NPV of zero over the period of interest?':

- An NPV of zero ensures that the prices are cost based, as they would have to be in a fully competitive market, neither under- nor over-recovering total costs (including a return on capital employed) over the lifetime of the project.
- Consistency of prices with trends in the underlying costs of production and assumed contestability of the market ensures that those prices are reflective of those that a (hypothetical) new entrant into the market at each point in time would charge.

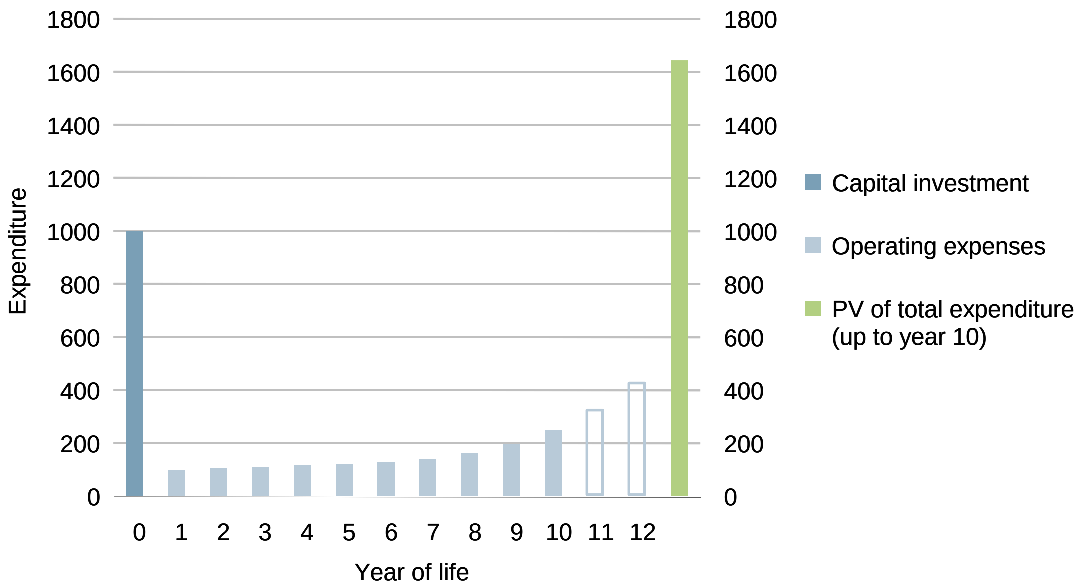
The inputs to the calculation are illustrated in Figure A.1.

Figure A.1: Economic depreciation inputs [Source: Analysys Mason, 2018]



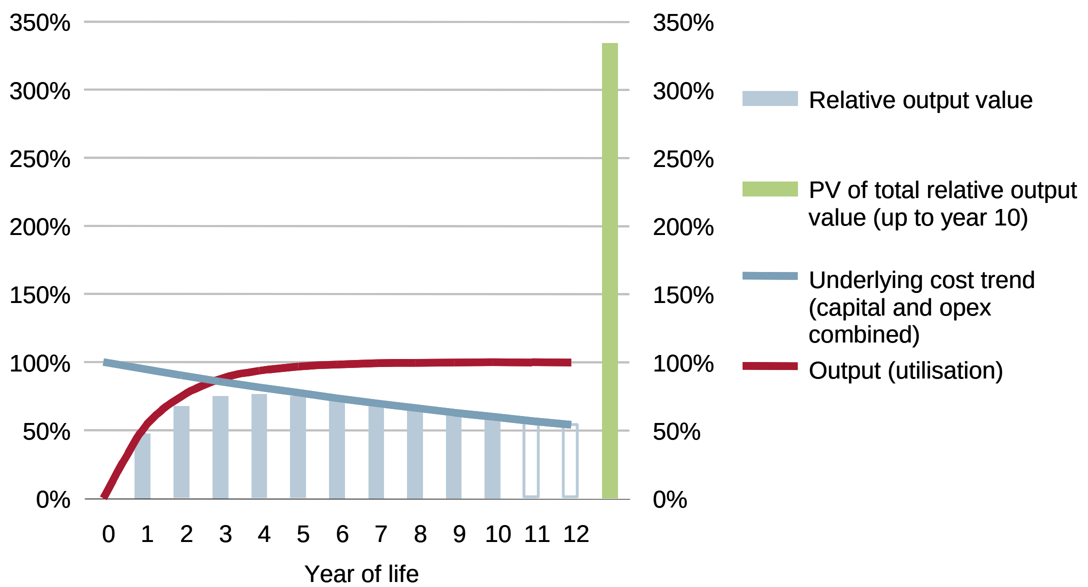
The present value (PV) of total expenditure, over say ten years, is calculated as shown in Figure A.2.

Figure A.2: PV of total expenditure over ten years [Source: Analysys Mason, 2018]



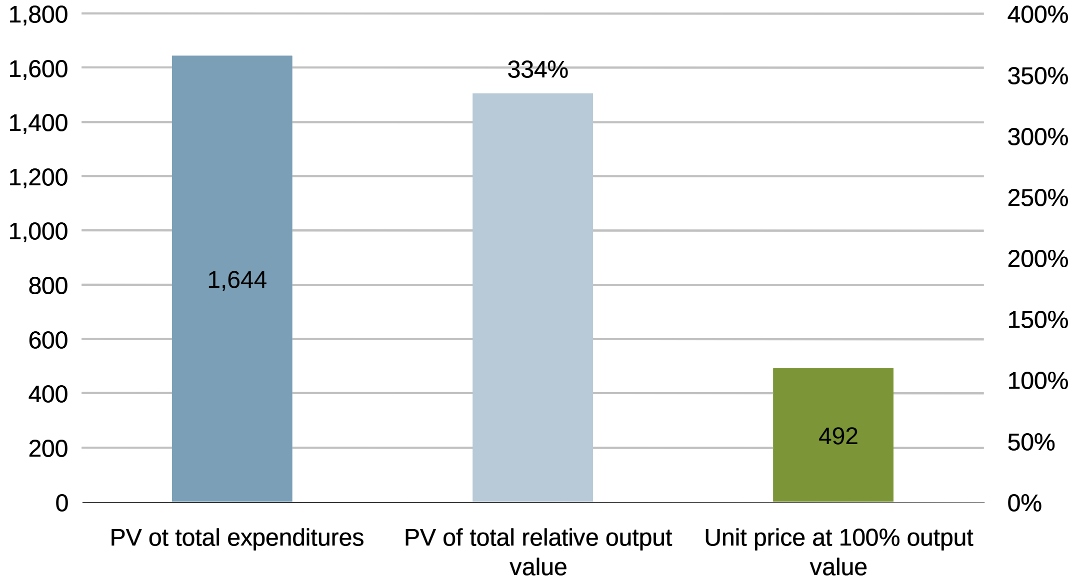
Then the PV of total *relative output value* is calculated over the same ten-year period. Relative output value is the product of asset utilisation multiplied by the (declining) price trend, and a relative measure of the revenue which can be earned from the asset. This is illustrated in Figure A.3.

Figure A.3: PV of total relative output value over ten years [Source: Analysys Mason, 2018]



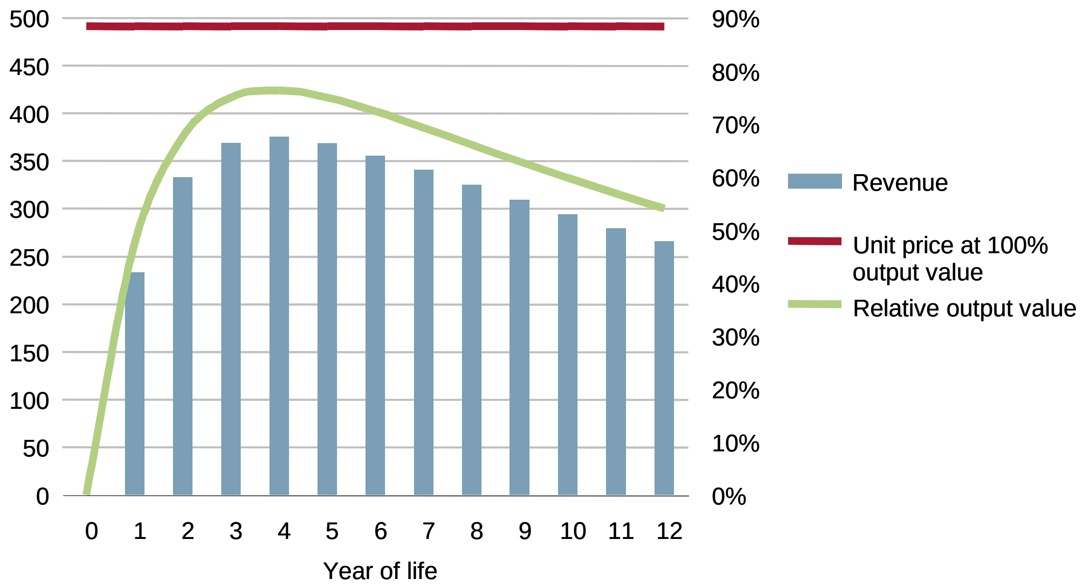
If we divide the PV of total expenditures by the PV of total relative output value, we obtain the measure of *unit price* at 100% of output value – i.e. revenue, or cost, per minute.

Figure A.4: Calculation of unit price [Source: Analysys Mason, 2018]



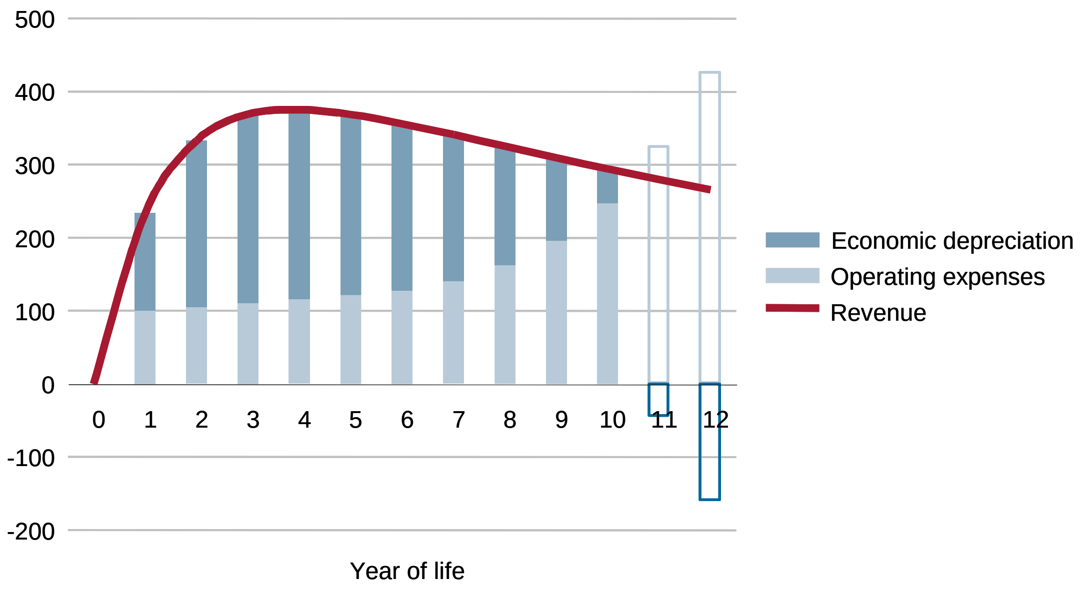
This unit price is then multiplied by the profile of relative output value to give overall output value, or revenue, as shown in Figure A.5.

Figure A.5: Calculation of revenue [Source: Analysys Mason, 2018]



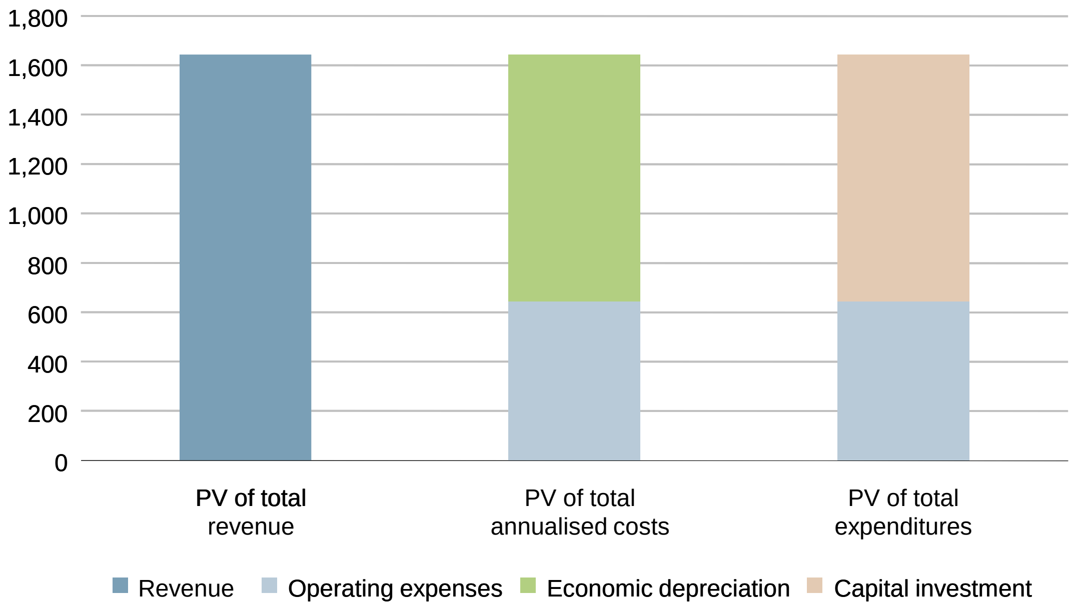
Economic depreciation specifically is the difference between revenues and operating expenditures, although it is often used to describe the overall depreciation profile (i.e. the recovery of costs through revenues). The economic lifetime of the asset is determined by when the asset operating expenditures exceed the revenues which can be earned from the asset – in this example, ten years. It is possible to determine the economic lifetime endogenously through iteration (e.g. by checking whether opex exceeds revenues in the eleventh year) or exogenously by making an external assumption (e.g. the economic lifetime of this asset will be *x* years). The overall economic depreciation profile is shown in Figure A.6.

Figure A.6: Economic depreciation profile [Source: Analysys Mason, 2018]



It can be confirmed that the calculation is overall NPV zero: the PV of revenues should equal the PV of expenditures and the PV of total cost recovery. This is illustrated in Figure A.7.

Figure A.7: NPV zero confirmation [Source: Analysys Mason, 2018]



Variants of economic depreciation exist; for example:

- operating expenditures can also be "depreciated", treating them as a (PV of) expenditures just like capital investment and recovering them from the profile of revenue according to operating expenditure price trends
- the calculation can be performed over a range of asset vintages by amalgamating the timeframe of expenditures into a single, overall, expenditure present value
- under the assumption of **constant output**, the economic depreciation profile equates to a **tilted annuity**.

-

Annex B List of fixed core NGN assets

A list of assets that would be modelled under the assumed fixed core NGN architecture is shown below in Figure B.1.

Figure B.1: NGN assets required for IP broadband access platform approach [Source: Analysys Mason, 2018]

Network asset	Asset description
OLT	This is where the first point of concentration of traffic occurs in a fibre access network
DSLAM	This is where the first point of concentration of traffic occurs in a copper access network
Ethernet switch	It is used to aggregate the traffic
Edge router	It is used for routeing the traffic from the access layer to the core nodes or to another DSLAM/OLT located within the same aggregation node, and vice versa
Core router	A core router is used for routeing the traffic between aggregation and core nodes, and between core nodes
Core switch	Core switches are used to aggregate the traffic
TGW	The TGW translates the TDM-based voice coming from other networks to IP for transit over the next-generation core network
Session border controller (SBC)	The SBC monitors the IP interconnection traffic and manages the QoS of the interconnection traffic; it controls the per-call (or per-session) bandwidth allocation at the borders of the network. It also provides security between the different network domains (e.g. network address translation, stopping denial of service attacks, etc.)
Call server/softswitch (CS)	The softswitch oversees the voice traffic
Broadband remote access server (BRAS)	Among other functions, the BRAS manages the QoS requirements for the broadband subscribers
RADIUS	Server that performs authentication and authorization functions
Domain name server (DNS)	Server that translates the domain names into its corresponding IP address
Clock	The clock performs the synchronization functions

Annex C Glossary of acronyms

AGW	Access gateways
ANACOM	Autoridade Nacional de Comunicações
ATM	Asynchronous transfer mode
BAP	Broadband access platforms
BRAS	Broadband remote access server
CAPM	Capital asset pricing model
CCA	Current cost accounting
CDMA	Code division multiple access
CMTS	Cable modem termination system
CS	Circuit switched
DECO	Portuguese Association for Consumer Protection
DLCS	Digital loop carriers
DNS	Domain name system
DSL	Digital subscriber line
DSLAM	Digital subscriber line access multiplexer
EC	European Commission
ED	Economic depreciation
EU	European Union
FAC	Fully allocated cost
FTR	Fixed termination rate
FTTH	Fibre to the home
FTTN	Fibre to the node
GPON	Gigabit passive optical network
HCA	Historical cost accounting
IMS	IP multimedia subsystems
IP	Internet protocol
IPTV	Internet protocol television
LRAIC	Long run average incremental cost
LRIC	Long run incremental cost
MDF	Main distribution frame
MEA	Modern equivalent asset
MPLS	Multi-protocol label switching
MSAN	Multi-service access nodes
NGA	Next generation access
NGN	Next generation network
NPV	Net present value
NRA	National regulatory agency

NTP	Network termination point
OLT	Optical line terminal
OTT	Over the top
PSTN	Public switched telephone network
PTP	Point to point
PV	Present value
QOS	Quality of service
SBC	Session border controller
SDH	Synchronous digital hierarchy
STM	Synchronous transfer mode
TDM	Time division multiplexing
TGW	Trunk gateway
TV	Television
UK	United Kingdom
VDSL	Very-high-bitrate DSL
VOD	Video on demand
VOIP	Voice over Internet protocol
WACC	Weighted average cost of capital
WDM	Wave division multiplexing