Annex 4: LRAIC MRP

Development of the Danish LRAIC model for fixed networks

Model Reference Paper

23 October *2019*

Contents

1. Introduction

1.1. Context

The telecommunications market in Denmark is ruled under the Danish Telecommunications Act[1] (hereinafter, the Act). Its main purpose is to promote an efficient and innovative market for electronic communications networks and services for the benefit of end-users.

The Act lays out in its fifth chapter the guidelines for the sector specific regulation in the telecommunications market, detailing how the analyses of the competitive situation should be performed, including markets definition, the identification of providers with Significant Market Power (SMP) and the potential obligations that could be imposed to regulate providers with SMP.

Particularly, the Act outlines that it is the Danish Business Authority (Erhvervsstyrelsen) (i.e. the DBA) duty to analyse the relevant markets and assess the potential obligations to be imposed on SMP operators. The analysis carried out by DBA for the relevant wholesale broadband markets (current market 3A and market 3B) resulted, since 2003, in a price control obligation on the access network services of the SMP. The enforcement of this obligation is performed through the LRAIC model.

Since LRAIC costs were first calculated in 2003, the model developed by DBA has been subject to a number of revisions and updates, in line with market developments. The latest major update of the cost model took place in 2013, with a small update in 2017 that made the model capable of excluding geographical areas from the cost calculation to allow the model to exclude areas where price regulation has been lifted. However, the relevant changes that have occurred since then in the fixed Danish market require a new update of the fixed LRAIC model to make sure it is representative of the current situation and can fulfil DBA's regulatory needs. This is the reason behind the update of this Model Reference Paper (hereinafter, the 'MRP').

DBA has chosen Axon Partners Group (hereinafter, 'Axon') to assist DBA in this project.

This document constitutes the draft Model Reference Paper, which will set the roadmap for the update of the model.

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[1] https://www.retsinformation.dk/forms/r0710.aspx?id=161319, Act no. 128, 7th February 2014 with amendments (Teleloven).

At this point, the document seeks comments from the industry through a public consultation process. The feedback received from stakeholders will be considered in the development of the final MRP.

This MRP has been prepared based on the existing methodological guidelines followed by DBA, as reflected in the MRP from July 2013[2]. The geographical adjustment from November 2017[3] has also been taken into consideration when drafting this document.

1.2. Structure of the document

This document has been built starting from the final MRP published in July 2013. The sections included are as follows:

- **Section 1**: Introduction
- **Section 2**: Costing Methodology
- **Section 3**: Networks to be modelled
- **Section 4**: Types of costs and costs allocations
- **Section 5**: Model implementation
- **Section 6**: Model outputs
- **Section 7**: LRAIC model validation and update process
- **Section 8:** Appendix

[2] DBA, Final Model Reference Paper, July 2013. Link: https://erhvervsstyrelsen.dk/sites/default/files/2019-03/Metodepapir01_lraic_mrp_final.pdf

[3] DBA, Specification Document, November 2017. Link: https://erhvervsstyrelsen.dk/sites/default/files/2019-03/GB_modeldokumentation_180119.pdf (see grey adjustments).

2. Costing Methodology

2.1. Cost orientation methodologies available to DBA

2.1.1. Legal Context

As part of its responsibilities in monitoring the telecommunications companies, and in particular in regulating the network access price control, DBA can require service providers with Significant Market Power (SMP) to meet certain pricing requirements.

According to the Price Control Order[4], DBA can choose between several price control methods when it comes to determining regulated prices:

> *"Specification of pricing requirements, cf. section 46(1) of the Act on Electronic Communications Networks and Services, shall be based on one or more of the following price control methods:*
>
> 1. *The long-run average incremental cost (LRAIC) method*
> 2. *Historic costs*
> 3. *Retail minus*
> 4. *Requirement of reasonable prices"*

DBA has currently determined maximum wholesale prices for TDC, which has been designated as an SMP operator, in a number of fixed network markets[5], including:

- Wholesale market for fixed-network termination (market 1)[6];
- Wholesale market for local access (market 3A)
- Wholesale market for central access (market 3B).

As a consequence, when choosing among cost orientation methods, DBA can select between two alternatives: "LRAIC" and "historic costs". Normally LRAIC would be using current cost/forward looking cost but as LRAIC in principle is a method to distribute cost between services, it could in theory be based on historical costs (partly or fully). As per the MRP published by DBA in 2013, the LRAIC costing approach is to be adopted in the implementation of the fixed LRAIC model in Denmark.

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[4] DBA, Executive Order on Price Control Methods, dated 27 April 2011.

[5] European Commission, Commission Recommendation on relevant product and service markets within the electronic communications sector susceptible to ex ante regulation, dated 9 October 2014.

[6] Several other operators are LRAIC-based regulated for market 1.

2.1.2. LRAIC methodology

2.1.2.1. Definition of LRAIC

LRAIC is "*the long run average incremental cost of providing either an increment or decrement of output, which should be measured on a forward-looking basis*".

The LRAIC approach enables one to mimic the level of costs **in a competitive and contestable market**:

"*Long-run incremental costs (LRIC) based on an* ***efficient deployment of a modern asset reflect the level of costs that would occur in a competitive and contestable market****. Competition ensures that operators achieve a normal profit and normal return over the lifetime of their investments (i.e. in the long run). Contestability ensures that existing providers charge prices that reflect the costs of supply in a market that can be entered by new players using modern technology.*

Together these ensure that inefficiently incurred costs are not recoverable and require a forward-looking assessment of an operator's cost recovery (as a potential new entrant is unconstrained by historical cost recovery)."

In Denmark, the Price Control Order supports the use of the LRAIC method stating that:

> *"(1) Where the LRAIC pricing method is used; the total price for a network access product may not exceed the sum of the long-run average incremental costs associated with the network access product in question.*
>
> *(2) Only efficiently incurred costs may be included, using efficient modern technologies."*[7]

Further, as determined in EC's 2013 Recommendation[8], replacement costs should be considered when determining the cost base of the model (see section '2.1.3 Relevant cost standard').

[7] DBA, Executive Order on Price Control Methods (Section 3 Networks to be modelled), dated 27 April 2011.

[8] EC, Commission Recommendation on consistent non-discrimination obligations and costing methodologies to promote competition and enhance the broadband investment, dated 11 September 2013.

2.1.2.2. The bottom-up approach

From 2013, the implementation of the fixed LRAIC model has been shifted to a full bottom-up methodology.[9]

Bottom-up models use demand data as a starting point and model an efficient network, using economic and engineering principles, which is capable of serving that level of demand. Under a bottom-up approach, the model (re)builds a (hypothetical) reasonably efficient network, reflecting to a certain extent the network of the modelled operator. The network is modelled accordingly, in order to deliver electronic communications services and to satisfy the demand for these services. The bottom-up results will be reconciled with data from the SMP operator(s).

2.1.3. Relevant cost standard

There are two cost standards for asset valuation commonly accepted by NRAs and international institutions (e.g. ITU, EC) in the development of cost models:

- **Historical Cost Accounting (HCA)** is the average price paid historically by an operator to acquire an asset, based on its financial registries.
- **Current Cost Accounting (CCA)** reflects the current and expected market value of the assets.

Although current cost accounting has been broadly accepted by most NRAs in the development of Bottom-Up models for mobile networks, there have been several discussions among regulators on the suitability of valuating fixed operators' civil infrastructure (for instance copper access network, civil works and ducts) according to Current Cost Accounting, as it may lead to an overestimation of access services' costs.

In this sense, in its 2005 Copper Statement[10], Ofcom concluded, referring to civil infrastructure assets, that "*The value of the RAV (Regulatory Asset Value) is set to equal the closing HCA value for the pre 1st August 1997 assets for the 2004/5 financial year*" whereas it approved the "*use of current cost accounting as at present for assets deployed from 1st August 1997 onwards*".

[9] The alternative to a bottom up model is a top down model. With top-down (TD) modeling, cost inputs are taken from the operator's accounting data and are allocated to different services on the basis of the causality relation between costs and services.

[10] Ofcom, Valuing copper access – Final statement, dated 18 August 2005

In similar fashion, the EC's Recommendation of 2013 'on consistent non-discrimination obligations and costing methodologies to promote competition and enhance the broadband investment environment'[11] establishes clear guidelines in order to avoid such over-recovery of civil engineering related costs. Particularly, the EC's Recommendation of 2013 states that:

> *"(33) Valuation of the assets of such an NGA network at current costs best reflects the underlying competitive process and, in particular, the replicability of the assets.*
>
> *(34) Unlike assets such as the technical equipment and the transmission medium (for example fibre), civil engineering assets (for example ducts, trenches and poles) are assets that are unlikely to be replicated. Technological change and the level of competition and retail demand are not expected to allow alternative operators to deploy a parallel civil engineering infrastructure, at least where the legacy civil engineering infrastructure assets can be reused for deploying an NGA network.*
>
> *(35) In the recommended costing methodology the Regulatory Asset Base (RAB) corresponding to the reusable legacy civil engineering assets is valued at current costs, taking account of the assets' elapsed economic life and thus of the costs already recovered by the regulated SMP operator. This approach sends efficient market entry signals for build or buy decisions and avoids the risk of a cost over-recovery for reusable legacy civil infrastructure. An over-recovery of costs would not be justified to ensure efficient entry and preserve the incentives to invest because the build option is not economically feasible for this asset category.*
>
> *(36) The indexation method would be applied to calculate current costs for the RAB corresponding to the reusable legacy civil engineering assets. This method is preferred due to its practicability, robustness and transparency. It would rely on historical data on expenditure, accumulated depreciation and asset disposal, to the extent that these are available from the regulated SMP operator's statutory and regulatory accounts and financial reports and on a publicly available price index such as the retail price index.*
>
> *(37) Therefore, the initial RAB corresponding to the reusable legacy civil engineering assets would be set at the regulatory accounting value, net of the*

[11] EC, Recommendation on consistent non-discrimination obligations and costing methodologies to promote competition and enhance the broadband investment environment, dated 11 September 2013

accumulated depreciation at the time of calculation and indexed by an appropriate price index, such as the retail price index.

(38) The initial RAB would then be locked-in and rolled forward from one regulatory period to the next. The locking-in of the RAB ensures that once a non-replicable reusable legacy civil engineering asset is fully depreciated, this asset is no longer part of the RAB and therefore no longer represents a cost for the access seeker, in the same way as it is no longer a cost for the SMP operator. Such an approach would further ensure adequate remuneration for the SMP operator and at the same time provide regulatory certainty for both the SMP operator and access seekers over time."

Based on the previous directives and recommendations from the European Commission, it becomes apparent that current costs should be used to reflect the regulatory value of most assets in order to send efficient market entry signals for build or buy decisions. Nevertheless, the EC's 2013 Recommendation provides room for adjustments to account for the accumulated depreciation of the reusable civil engineering assets. This is derived from the EC's understanding that, unlike active equipment and the transmission medium (e.g. fibre), civil infrastructure assets are unlikely to be replicated and thus, a buy rather than a build decision should be promoted in these cases.

While DBA agrees that the active equipment could be indeed replicated (i.e. deployment of own assets could be economically feasible for an access seeker), it could be argued that in order for the transmission medium to be replicable, an access seeker must be able to rely on the underlying civil infrastructure of the access provider. Therefore, a necessary condition to allow the replicability of the transmission medium is that access seekers can access the underground access network of the infrastructure operator, for instance, through ducts. Otherwise, the transmission medium should be considered not to be replicable and thus, it should also be valued at current costs net of cumulated depreciation.

Given the technical complexities resulting from it, the EC's 2013 Recommendation requires a careful assessment, especially in countries such as Denmark, where multiple access networks coexist (copper, fibre and coax). Depending on the architecture and network topology, different circumstances may apply that need to be assessed on their own. In particular, the key methodological consideration to be borne in mind is that the model's results shall provide the appropriate build-or-buy signals to the market.

DBA's assessment of the situation applicable to each access network is presented in the paragraphs below.

Copper

In today's environment, copper access networks are increasingly becoming obsolete as they are not capable of delivering the increasing broadband speeds demanded by the subscribers. As a result, no fixed-line operator would think about the possibility of engaging into the deployment of a copper-based access network.

Considering this situation, it would be inappropriate for NRAs to aim at fostering infrastructure-based competition (i.e. build decisions) in such networks. Instead, service-based competition (i.e. buy decisions) should be encouraged.

Further, copper networks have been present for many years and, therefore, it could be expected that a relevant portion of their costs have already been recovered by the SMP operator. In this context, a CCA approach would probably lead to an over-recovery of costs by the SMP operator.

Based on the previous considerations, DBA concludes that copper cable assets and their related civil infrastructure should be "*valued at current costs, taking account of the assets' elapsed economic life and thus of the costs already recovered by the regulated SMP operator*", as per the EC's 2013 recommendation, article (35) on page 5. This means that the fully depreciated copper cable assets and related civil infrastructure assets as per the SMP operator's financial statements will generate no costs in the model.

At the same time, DBA also acknowledges that upgrades have been implemented in copper access networks, bringing fibre to the cabinet (an intermediate location between the Local Exchange and the end user). These improvements are rather new and, in many cases have implied new investments in civil infrastructure. These fibre-related deployments with regards to the broad copper access network shall be valued based on a CCA approach. DBA will analyse the extent to which fully depreciated assets play a role in this section of the network and decide if any adjustment to these assets should be applied in order to avoid an over-recovery of the costs borne by the modelled operator. In principle, DBA believes this adjustment will not be required.

In summary:

- Copper cable and the related civil infrastructure assets shall be "*valued at current costs, taking account of the assets' elapsed economic life and thus of the costs already recovered by the regulated SMP operator*", as per the EC's 2013 recommendation, article (35) on page 5.

- Active network elements and new investments in civil infrastructure to deploy fibre to improve the capacity of the networks should be valued following a pure CCA approach.

Fibre

In the case of Fibre to the home (FTTH) networks, it could be feasible and is advisable to promote both competition and investment by SMP and non-SMP operators. In this case, the cost of these elements will be allocated proportionally to each of the access networks for which they are used. This allocation procedure is further explained in section '5.6.1 Allocation of shared costs of civil infrastructure'.

Coax

From a network and historical standpoint, coax networks could be considered to be similar to copper networks. Therefore, while coax is not currently regulated in Denmark, we observe that if it is to be regulated in the future, similar considerations applicable to copper networks will also apply for coax networks.

Particularly, similarly to copper networks we observe that no operator would today build a pure coax network, as these would not be able to compete with modern fibre networks. Thus, the efficient market entry signals for coax networks would have to imply a preference for "buy" alternatives.

In addition, also similarly to copper networks, coax networks have been present for a long time in Denmark and thus, a relevant part of the coax-related costs may have already been recovered by the SMP operator. In this context, the adoption of a pure CCA approach would probably lead to an over-recovery of the costs.

Based on the previous considerations, assets belonging to the coax access network should be valued following the same methodology to copper networks, this is:

- Coax cable and the related civil infrastructure assets shall be "*valued at current costs, taking account of the assets' elapsed economic life and thus of the costs already recovered by the regulated SMP operator*", as per the EC's 2013 recommendation, article (35) on page 5.
- Active network elements and new investments in civil infrastructure to deploy fibre to improve the capacity of the networks, should be valued following a pure CCA approach.

2.1.3.1. Summary of the asset valuation approaches

The following table presents a summary of the asset valuation approaches that should be followed for each of the network elements considered in the different access networks.

Network	Valuation should exclude fully depreciated assets	Valuation should not exclude fully depreciated assets
Copper networks	• Copper cable. • Civil infrastructure used to hold copper cables.	• New assets (including civil infrastructure) related to fibre deployments within the broad copper network. • Active equipment.
Fibre networks		• All passive and active network elements.
Coax networks	• Coax cable. • Civil infrastructure used to hold coax cables.	• New assets (including civil infrastructure) related to fibre deployments within the broad coax network. • Active equipment.

Illustration 2.1: Summary of the asset valuation approaches [Source: Axon Consulting]

2.1.3.2. Practical implementation of EC's recommendations

As per the EC's 2013 Recommendation, the set of assets listed under the column "Valuation should exclude fully depreciated assets" of Illustration 2.1, should be "*valued at current costs, taking account of the assets' elapsed economic life and thus of the costs already recovered by the regulated SMP operator*". The European Electronic Communications Code (EECC) further reinforces the indications provided in the EC's 2013 recommendation on this particular subject.

In order to implement this directive, it is firstly important to identify the costs from fully depreciated assets that have already been recovered by the modelled operator. These refer to the assets that no longer generate any depreciation costs but are still being used by an operator. This is likely to be the result of a misalignment between the useful life considered for an asset and its technical useful life. These fully depreciated assets should not be considered to avoid an overvaluation of the Regulatory Asset Base.

Taking the adjustment of fully depreciated assets into consideration, the following steps shall be adopted to determine the proper cost references under the EC's 2013 recommendation:

- **Step 1:** Identify the volume of network elements (km of cables, km of ducts, number of poles, etc.) deployed in the network based on the technical registries of the operator.

- **Step 2:** Extract the gross book value (GBV) of the assets that still generate costs (i.e. assets that are not fully depreciated), based on the data available in the financial accounts of the operator (Fixed Asset Registry) and DBA's previous fixed LRAIC models. In practice, the analysis of the assets that are not generating costs will be done by considering the higher of the useful lives considered by the SMP operator in its financial statements and by DBA in its previous fixed LRAIC Bottom-Up models[12].
- **Step 3:** Calculate an adjusted Gross Replacement Cost (GRC), aligned with EC's recommendation, of these assets based on an indexation methodology using, for instance, the construction cost index for civil engineering projects reported by the Statbank[13].
- **Step 4:** Divide the adjusted-GRC obtained in Step 3 by the number of units identified in Step 1 to get the reference unit price of the asset.

Main criterion 1: A Current Cost valuation should be adopted to set the unit costs of the assets in the Bottom-Up cost model. Nevertheless, the GRC originated from fully depreciated assets should be excluded for the categories listed in the column "Valuation should exclude fully depreciated assets" of Illustration 2.1.

2.1.3.3. Consideration of public funding for network deployment

When determining the relevant cost base of the model, it needs to be acknowledged that Danish operators have benefited from subsidies from the Danish Energy Agency (Energistyrelsen) to provide FTTH coverage in different areas of the country. Based on the data available to DBA, the subsidies received throughout 2018 are estimated at 23.593 DKK/connected household.

DBA believes that this amount is substantial enough and, consequently, that public funding for the deployment of FTTH networks should be accounted for in the model.

Supporting criterion 1: The model will take the public funding that operators have received from the Danish Energy Agency (Energistyrelsen) in the deployment of broadband networks into account. The applicable public funding will be deducted from

[12] E.g. if an asset was purchased in the year 2000 and the useful life considered in the previous fixed LRAIC model for this asset class is 30 years, then the asset will not be considered fully depreciated, regardless of the asset's status in the financial statements of the SMP operator.

On the other hand, if the useful life considered in the financial statements of the SMP operator is longer than the useful life of the previous fixed LRAIC model, then the useful life from the financial statements of the SMP operator will be applied.

[13] Index - BYG61: Construction cost indices for civil engineering projects (2015=100) by index type and unit Source: Statbank. Link: https://www.statbank.dk/statbank5a/SelectVarVal/Define.asp?MainTable=BYG61&PLanguage=1&PXSId=0&wsid=cftree

the cost base considered in the cost model, to ensure that it reflects the actual costs incurred by the modelled operator.

2.2. Focus on LRAIC

2.2.1. LRAIC

As defined by DBA, "*LRAIC is the long run average incremental cost of providing either an increment or decrement of output, which should be measured on a forward-looking basis*".

Long run is understood as a time horizon, in which all inputs including the cost of equipment are allowed to vary as a consequence of market demand. Average denotes that the costs connected to the production of the relevant service (within the costs of providing the whole increment) are divided by the corresponding total traffic in order to return an estimate of the average incremental costs of the service. There are several definitions of the term increment, which is why this subject is discussed in detail below (see section '2.2.2 Defining the Increment').

The definition of forward-looking costs depends on the time frame considered and on the asset valuation methodology selected, which is outlined in section '2.1.3 Relevant cost standard'.

2.2.2. Defining the Increment

Incremental costs are the costs of providing either an increment of output when other increments of demand are unchanged.

Increments can be defined in a number of ways. Possible definitions of the increment include:

- marginal unit of demand for a service;
- total demand for a service;
- total demand for a group of services;
- total demand for all services.

The illustration below illustrates these different definitions for the case of a company producing 5 different services (A to E):

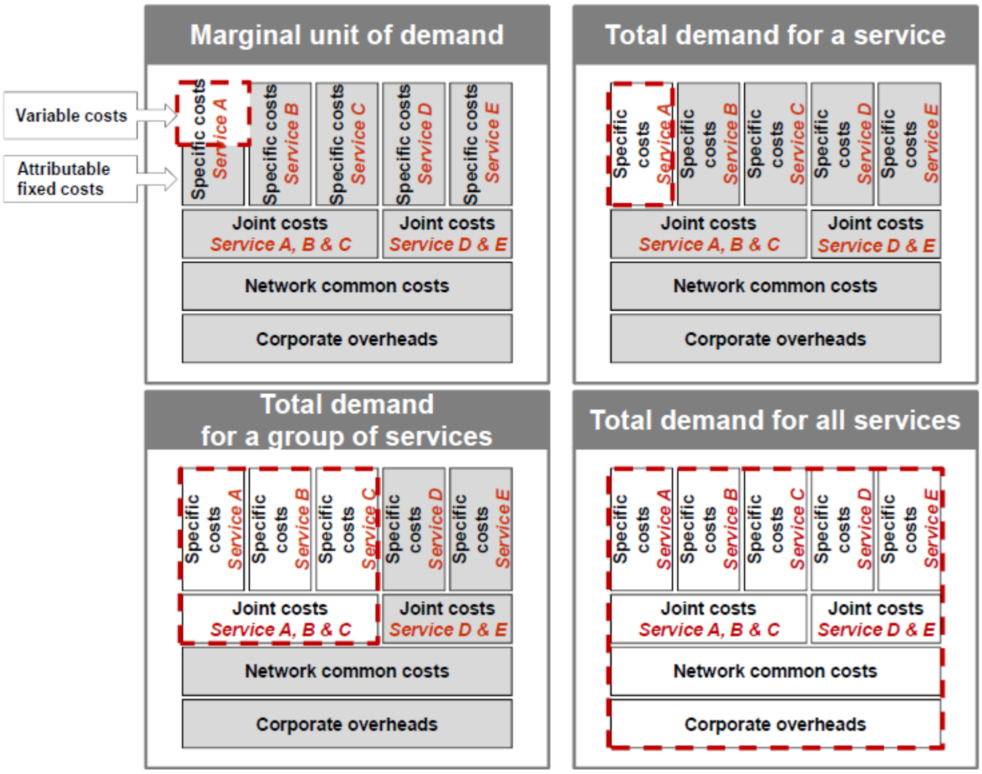

Illustration 2.2: Illustration of possible increment definitions [Source: DBA - Final MRP (July 2013)]

The larger the increment, the larger the share of joint and common costs is accounted for.

For example (see Illustration 2.2):

- If service A is the increment, no joint and common costs are taken into account;
- If the increment is service A, B and C together, a share of costs that are joint to services A, B and C are taken into account.

Calculating the costs based on small increments means that the calculated incremental costs benefit to a great extent from the network economies of scale (as it would support no or limited share of joint and common costs).

In the opposite case, the adoption of a large increment (for instance, in the case of a fixed network, all services using the access network) means that all services benefit to the same extent from economies of scale. In these cases, all services bear a share of joint and common costs.

2.2.3. Implications of LRAIC

LRAIC results in prices that are above marginal cost. The existence of fixed costs means that charging prices on the basis of marginal costs does not allow the SMP operator(s) to recover the cost of investments in its network, even when its costs are efficiently incurred.

Setting prices using LRAIC permits the recovery of intra-increment fixed costs, in the process of promoting forward-looking investment decisions. It might also reduce market distortions. If prices were based on marginal cost, the SMP operator(s) would have to recover many shared/fixed costs from its other (non-regulated) services, which might distort the competition process in favour of other competing operators in those markets.

Even all-service increment LRAIC-prices does not permit the SMP operator(s) to recover inter-increment common costs. In order to allow full recovery of efficiently incurred costs, an adjustment to LRAIC should be applied to take account of such common costs.

Finally, it should be noted that since LRAIC is a forward-looking concept, the optimised network should be modelled as if it was already in place. This means that no migration costs (additional costs associated with moving from the existing network to the optimised network) should be included.

Main criterion 2: The LRAIC model should be based on forward-looking long run average incremental costs. No migration costs should be included. The LRAIC model should allow coverage of common costs. These costs should be shown separately.

2.3. Time horizon of the cost model

Given that the unit costs of services are calculated depending on the demand at a specific point in time, the period of time modelled will be crucial in the scope of the possible analyses of the model's results.

Fixed networks have been well-established in Denmark for many years, covering the vast majority of the population. In order to take into consideration the existing roll-out of fixed networks, obtain a precise valuation of civil infrastructure assets, and to be able to calibrate the model, it is deemed necessary that the time frame considered shall begin in the past.

DBA does not consider it essential to go back to the take-up stages of fixed networks, as it would add complexity to the modelling process and would involve a significant burden on operators as detailed information for the historical period would be required (for instance, historical demand, unit cost and financial information). However, it recognizes that in order to maximize the robustness of the results obtained under an economic depreciation (please refer to section '4.4 Depreciation Methodologies' for further indications on the selected depreciation methodology), it is convenient to consider a representative sample of past years in the model. Considering this situation, and based on the feedback received in the consultation process, the model's timeframe will begin in 2005, provided that operators report the relevant historical information required to properly capture the historical period. If such information is not available, the initial year of the model will be adjusted to the first year for which data is available; this initial year will be 2018 or earlier.

With regards to the definition of the final year of the time frame, DBA has a strict requirement to obtain the service provisioning costs for 5 years from 2021. Further, it may also be convenient to consider some additional years in order to properly take into account the copper/coax migration trends to FTTH access networks, which may influence the results produced under the economic depreciation methodology. Considering this situation, and based on the feedback received in the consultation process, the model's timeframe will end in 2038, provided that operators report the forecasted data required to properly capture the future period. If such information is not available, the final year of the model will be adjusted to the last year for which data is available; this final year will not be before 2028.

While the inputs and network dimensioning algorithms will be defined only for the 2005-2038 period (or as otherwise concluded, based on the data provided by the operators), the implementation of economic depreciation (see section '4.4 Depreciation Methodologies'), requires demand to be defined, at least, throughout the useful life of the assets. Given that the civil infrastructure of fixed networks can last up to 40-50 years, the model should include a time-frame period that goes at least until 2070 for the calculations related to the implementation of economic depreciation.

Main criterion 3: The model will calculate the service provisioning costs from 2005 to 2038, or as otherwise concluded, based on the data provided by additional years may be included based on the availability of information. The modelling timeframe will at least cover the 2018 – 2028 period. Additionally, it will incorporate a time-frame up to, at least, 2070 to properly implement the economic depreciation algorithms.

3. Networks to be modelled

3.1. Scope of the model and definition of the increment

3.1.1. Introduction to the model's networks and increment

Several services require an estimate of the costs of the traffic-sensitive parts of the network (e.g. traffic component of the bitstream access "BSA"), while others require an estimate of the costs of the line-sensitive parts (e.g. lease of non-equipped infrastructure sections and other sub-elements in access networks "raw copper" including sub-loops). However, there is no need to separate the core and access models or increments in order to achieve this objective.

Particularly, the costs associated to access services and the costs associated to traffic/core services are clearly delimited. This means that all network costs can be attributed either to access or traffic/core services in a causal manner which, in turn, implies that there are no network costs that should be shared between these groups of services. As a result, having separate increments for these services would have no impact whatsoever over having a single increment, while increasing the complexity of the model.

Main criterion 4: A single model will be built, with a single increment comprising all access and traffic services. Costs of ancillary services (such as co-location, activation and interconnection points) will be calculated stand-alone as they are not directly related to the main network topology or architecture as such.

3.1.2. The core network

Costs in the core network are driven by the volume of traffic whereas costs in the access network are mainly driven by the number of lines (active and inactive). As volumes will increase with the number of subscribers (active lines), the number of active lines and the volume of traffic will be correlated to some degree.

Assets within the core network typically include:

- DSLAMs, OLTs or CMTS except line cards;
- Backbone/core routers;
- Transmission links between the exchanges;
- Optical fibre and trenching between all levels of core node locations.

It should be noted that in the case of FTTC, the DSLAMs located at the level of the street cabinet, even if physically in the access network, are considered as part of the core network (see section 5.4 Network dimensioning).

3.1.3. The access network

As defined above, costs in the access network typically depend on the number of customers, but not on the amount of traffic (except for the cable-TV network). Consistent with this, an alternative definition of the access network is that it allows the customer to send and receive traffic.

Both definitions suggest that the access network includes all cable and trenching costs associated with customer lines between the customer's premises and the concentrator. Furthermore, the definitions suggest that the access network includes the line card within the DSLAM/OLT/CMTS. This is consistent with the first view since line card requirements are generally driven by the number of subscribers or, more accurately, by the subscriber requirements for lines. It is also consistent with the second view since the line card is an essential part in sending and receiving traffic.

Assets within the access network include:

- The final drop wire to the customer's premise (although the cost associated with this drop wire, or its activation, might be captured through the connection charge);
- The trenching (in some cases ducted) between the final connection point and the remote or host DSLAM/OLT/CMTS;
- Copper, coax and optical fibre cables in this part of the network;
- Other assets such as manholes, poles and overhead cables (if used); and
- Line cards in the DSLAM/OLT/CMTS.

The model should enable to take into account the costs of the different access configurations, including:

- Copper
  - Copper-only access
  - FTTC (Fibre-To-The-Cabinet);
- FTTH

- PON[14] (Passive Optical Networks)
- PTP (Point To Point)

- Cable-TV, based on a DOCSIS 3.1 network.

In all of the above cases, the differences between deployment for multi-dwelling and single-dwelling homes shall be considered.

The model should make it possible to clearly identify non-traffic sensitive costs which are only subscriber-related. This would include, for example, the junction to the dedicated cable to the premise, the dedicated cable to the premise, and the network termination point within the premise.

In the particular case of coax networks, part of the elements considered in the access network (e.g. amplifiers and splitters) are not only driven by the number of lines but also by the spectrum reserved for each service. The model should reflect these different drivers in the allocation of the costs associated to these network elements. This means that network elements that are driven by the number of lines, such as civil infrastructure and cable assets, will allocate their costs to services based on the number of lines. On the other hand, network elements whose spectrum is reserved to different services, such as amplifiers and splitters, will be allocated to services based on the spectrum allotments.

Supporting criterion 2: For the cable-TV network, the model should apply different allocation rules for the network elements depending on whether they are dimensioned based on the number of lines (such as the civil infrastructure and the cables) or dependent on the spectrum reserved for each service.

3.1.4. Scope of the networks

As described above, the demarcation between access and core networks should be set at the line card. If the number of subscriber lines is increased while the volume of traffic is held constant the number of line cards will increase. If, on the other hand, the volume of traffic is increased while the number of lines is held constant the number of line cards will not generally change. The cost of line cards therefore depends on the number of subscribers, in common with the access network, and not the volume of traffic, unlike the core network.

[14] PON networks include, among others, GPON (Gigabyte Passive Optical Networks).

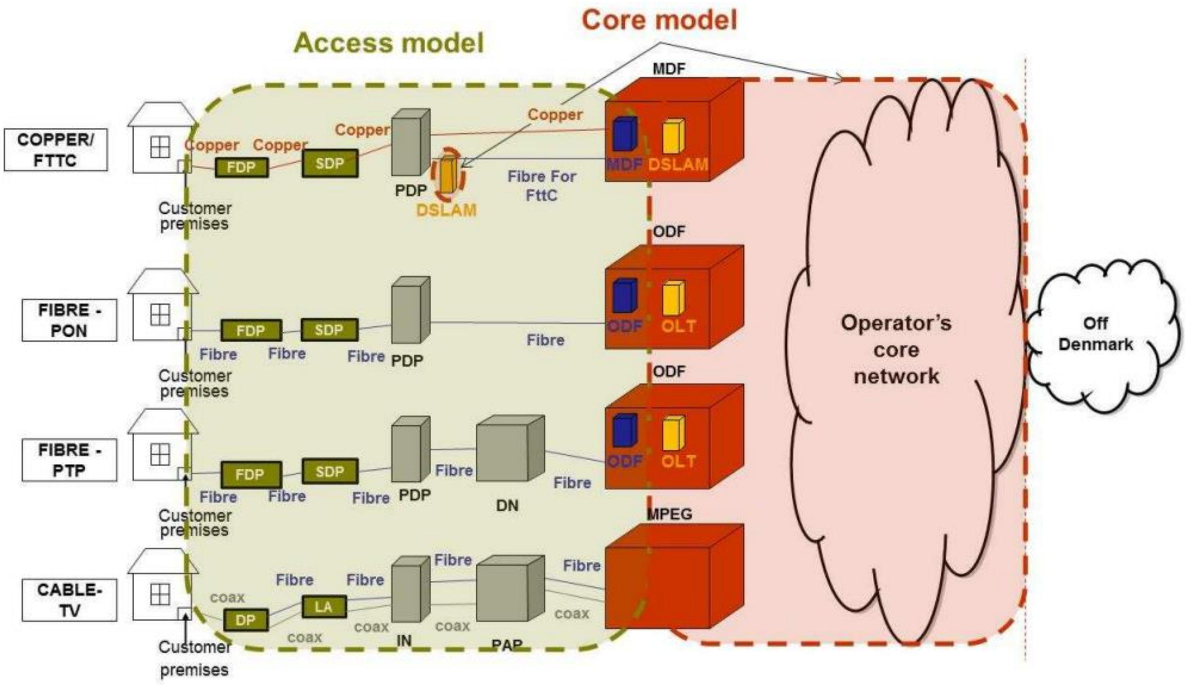

Illustration 3.1. Illustration of boundary between core and access networks (for illustrative purposes) [Source: DBA - Final MRP (July 2013)]

In the case of FTTC, the DSLAM located at the cabinet level belongs to the core network because it is an active asset whose cost is traffic related (although physically located in the access network).

Additionally, some trenches are used by the access network, some by the core network, and some are shared between the access and the core networks. The cost of trenches should be allocated between access and core networks in consistency with the realities observed in the actual networks.

Supporting criterion 3: The model should consider line cards as part of the access network. The DSLAM located at the cabinet (in the case of FTTC deployment) should be considered as part of the core network. The cost of trenches should be allocated between the core and access networks in consistency with the realities observed in the actual networks.

3.1.5. Modelled operator

The cost model should provide the service provisioning costs of the operators with Significant Market Power (SMP) in markets 3a and 3b. In the latest market review performed by DBA[15], TDC is the only operator designated to have SMP in both markets. Therefore, so far, the model should be primarily focused on TDC.

However, as detailed in section '2.3 Time horizon of the cost model', the model will need to be able to calculate services' costs for, in principle, the 2005-2038 period, or otherwise concluded based on data availability. This implies that, within the useful life of the model, other operators may eventually be designated as having SMP in any of these two markets and the model should be flexible enough to assess their costs, based on the actual network and costs of these operators.

Main criterion 5: The modelled operator(s) should be, at all times, the SMP operator(s) in markets 3a and 3b. For the time being, this implies that TDC is going to be the only modelled operator. Nevertheless, if any other operator is also designated to have SMP in markets 3a and 3b, the model should be ready to assess its costs following the methodology described in this document.

3.2. Services

This section describes the list of services that should be included in the LRAIC model. In addition, an introduction to the role that routing factors play in the cost allocation to services is presented later in this section.

It should be noted that all services relevant for cost calculation should be included in the model. A high-level overview of the list of services is presented below:

Service	Service Explication
Retail access *(Concerns copper, fibre and coaxial networks)*	Provision of a line suitable for voice/broadband/TV services and sold through the modelled operator's retail arm. One or more of these services may be provided over the same line. Retail access services will be included separately for each access technology (copper, fibre and coax).
Broadband to own customers *(Concerns copper, fibre and coaxial networks)*	Provision of broadband services to the own retail customers of the modelled operator(s). These services will be included separately for each access technology (copper, fibre and coax) and will be split per broadband speed.
IPTV and video services *(Concerns copper, fibre and coaxial networks)*	Provision of IPTV and other video services to end users.

[15] DBA, Market 3 – Broadband decisions, dated 17 August 2017

Service	Service Explication
VULA/BSA *(Concerns copper, fibre and coaxial networks)*	Provision of a data service to an end user, where a connection of specific quality can be set up from the subscriber to an access point in the modelled operator's network, from where the access seeker can route traffic to its own network. The modelled operator carries traffic over the access line and ensures transmission up to the access point. This access service will be included separately for each access technology (copper, fibre and coax). The applicable variants (for instance, based on the relevant access point) of the service will be included for each technology, namely: ▶ VULA/BSA – POI0 ▶ VULA/BSA – POI1 ▶ VULA/BSA – POI2 ▶ VULA/BSA – POI3
Copper unbundling *(Concerns copper networks)*	Allows an access seeker to provide services, including voice, TV and broadband, over the copper loop using its own equipment co-located with the termination block at the modelled operator's main distribution frame (MDF). Co-location at the MDF is offered by the modelled operator as a separate product. The unbundled cable runs from the network termination point (NTP) to a terminating block at the MDF.
Pair bonding *(Concerns copper networks)*	Access to BSA or copper unbundling using n copper pairs.
Ducts *(Concerns copper, fibre and coaxial networks)*	Access infrastructure for parts of or for the entire distance between a street cabinet and a network termination point
Fibre unbundling *(Concerns fibre networks)*	Allows an access seeker to provide services, including voice and broadband, over the fibre loop using its own equipment co-located at/by the modelled operator's cabinet or ODF, depending on the network architecture. The unbundled fibre runs from the network termination point (NTP) to the interconnection point (cabinet or ODF).
Dark Fibre *(Concerns fibre networks)*	Provision of unit fibre (dark fibre) access in order to reach any access point, either the end-user premises (access link), a concentration/unbundling point or even the bitstream handover point.
Leased lines *(Concerns fibre networks)*	Provision of one or more local tails for a permanent connection from a location, for retail customers, for other operators, or for internal use. The modems required for these locations will not be modelled explicitly, as is the case in previous LRAIC model. This includes IP/Ethernet leased lines. These leased lines should consider Virtual Private Networks (VPNs) All leased lines will be assumed to be provided on fibre networks.
Backhaul *(Concerns copper, fibre and coaxial networks)*	Access from a distribution point to a more centrally located node in the network. Includes both ducts and active fibre infrastructure.

Illustration 3.2. Overview of services to be included in the model [Source: DBA/Axon]

It should be noted that not all services that will be modelled will be regulated services. This is in order to ensure that all the costs borne by the modelled operator are effectively considered and economies of scope and scale are adequately presented in the cost model.

In terms of voice services, the European Electronic Communications Code[16] (EECC), approved on 11th December 2018, removed the obligation for NRAs to periodically set the applicable wholesale fixed and mobile termination rates in their home countries. As reflected in the EECC, "*[T]he Commission should establish, by means of a delegated act, a single maximum voice termination rate for mobile services and a single maximum voice termination rate for fixed services that apply Union-wide.*"

Despite the absence of a regulatory need to calculate voice services' costs, it could be argued that their consideration in the LRAIC model could be necessary to ensure a proper allocation of common costs to the different services. If voice services are not modelled, there could be criticism that the common costs that should be allocated to these services would be allocated to other services instead, thus overestimating their costs. On the other hand, DBA recognises that, in the absence of a regulatory need to calculate voice services' costs, removing them from the model would make the model less complicated and reduce both data collection and model updating processes for both the industry and DBA.

In order to assess the impact of not including voice services in the calculation of other services' costs, an international benchmark of the share of common costs that are allocated to voice services in four Bottom-Up models[17] was performed. The results of this analysis showed that, out of the four references consulted, the percentage of common costs allocated to voice services was never higher than 0.8% with an average of roughly 0.5%. Additionally, this percentage is even expected to decrease further in the future as broadband speeds increase (thus receiving a higher share of common costs) while the number of voice subscriptions presumably will continue to decline. This implies that removing voice services from the model would have a minor impact on the results obtained for the regulated services.

However, in order to ensure a comprehensive assessment of the costs to provide broadband services the model will allocate a reasonable percentage of the common costs (i.e. between 0.5 percent and 0.8 percent) to voice services. This percentage will be based on an analysis of voice costs in the existing model from DBA and will take into consideration

[16] EC, European Electronic Communications Code, dated 11 December 2018. Link: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972&from=en

[17] These included the models developed by the NRAs from Denmark, Belgium, Norway and Portugal.

the relative decrease of the weight of voice traffic due to the increase of broadband traffic over time.

Main criterion 6: The model should include all relevant access, broadband leased line, TV and ancillary services. **Main criterion 7**: The model will not include voice services. Including voice services in the model would complicate the model with a negligible impact on the cost calculation of regulated services. Consistently, voice-specific core platforms (e.g. MGW) will not be modelled either. The model will, however, allocate the relevant share of common costs to voice services based on an ad-hoc analysis from the existing LRAIC model. **Supporting criterion 4**: When dimensioning the network, the leased-lines traffic volume should include leased lines provided to retail customers, to other operators and to the network operator. Leased lines used by the network operator should not be double counted. The model should not calculate the costs of leased lines explicitly. Leased lines should only be included for dimensioning of the network and for ensuring that a fair amount of costs is allocated to leased line services as well. **Supporting criterion 5:** For PTP, both an unbundling product at the ODF and a BSA product will be modelled. For PON, both an unbundling product at the splitter and a BSA product will be modelled. **Supporting criterion 6[18]:** Bitstream services in coaxial networks should be aligned with the current wholesale commercial offers in the market.

3.2.1. Routing factors

Routing factors are a way of measuring, in equivalent terms, the usage of the assets by the different services. They are particularly important when dimensioning and allocating the costs of the core network because they are a measure of the intensity to which different services use different network elements.

Routing factors play two pivotal roles in cost models, namely:

- in assisting to put the volume measures for broadband services, leased lines and data services in the network on a common basis;

[18] This criterion is specific to the cable-TV passive access network model

- in determining costs per network element/cost category and, in turn, the cost of individual services.

The routing factors are comprised of two main parameters:

- **Usage Factors**. These are defined as the average frequency that a particular service uses a given network element (e.g. the number of times a broadband connection uses an IP router).
- **Conversion Factors**. They are responsible of converting the demand of the different services into equivalent units in consistency with the dimensioning driver of the network elements. For instance, even though two broadband services with different broadband speeds are both measured in "number of lines", in order to properly allocate the costs of the transmission assets (which are dimensioned based on Mbps) the demand of the two services needs to be expressed in Mbps.

Routing factors may be easier to identify for some services than for others. Alternative methodologies may need to be developed for some services to quantify their use of different elements of the core network.

For the access network, routing factors are also required in order to capture the right scope of costs for each service. As an example, for a wholesale product giving access to the local loop (from the end-user to the Central Office), the routing factors corresponding to higher-level layers of the network would need to be set to zero.

Supporting criterion 7: The model should show, for each service, routing factors or, if not possible, a consistent alternative measure of how, on average, each service uses the core network and the access network. The model should also be flexible enough to allow for changes in routing factors / alternative measures.

3.3. Technologies to be modelled

3.3.1. Core switching technologies

IP is the packet switching technology that is used in modern telecommunication networks. Next Generation Networks (NGNs) based on an all-IP core are rolled out in various European countries (both by incumbent and alternative operators), where networks are capable of handling all of the services previously routed across circuit switched networks.

This is also the technology that was only included in the previous LRAIC model. It does not appear necessary to modify this.

Supporting criterion 8: The model should only include IP packet switch technology.

3.3.2. Core transmission technologies

There are two main concerns when choosing the technology to be used in the transport network:

- the configuration of the various available transmission technologies; and
- the extent of optical transmission systems in the network.

3.3.2.1. Transmission technologies

In an NGN, there is no need for SDH transmission. The necessary functionality can be provided by the IP switching/routing equipment itself.

Supporting criterion 9: The model should not include SDH.

3.3.2.2. Optical transmission systems in the network

Improvements in laser technology have increased the capacity of optical fibre. Dense wavelength division multiplexing (DWDM) allows the combination of a number of wavelengths on a fibre so the capacity of a single fibre is increased even more.

From a top-down perspective, an all-IP network might well incorporate a considerable amount of DWDM equipment. However, it is most likely that this has occurred due to historical reasons of limited fibre availability within existing trenches and ducts. Choosing between digging up the streets to install additional fibre optic cables or installing DWDM equipment at relevant node locations, the latter option will probably prove to be more cost effective in most circumstances.

Nevertheless, from a bottom-up perspective, the number of fibres in each cable/duct/trench becomes a variable and thus no longer act as a constraint on the network design. Furthermore, the cost of rolling out more fibre cables (or cables with more fibres) is more cost efficient than installing DWDM.

There is however one case where the use of DWDM could be necessary in the LRAIC model which is for long distances. In this case, even a new operator building a new network would require DWDM.

Supporting criterion 10: The model should not include DWDM equipment in the core network, except for long distances.

3.3.3. Access technologies

In Denmark, as with most countries, the line from the customer to the closest exchange usually consists of a twisted copper pair with the individual pairs aggregated into larger cables at street cabinets for carriage to exchanges.

Since almost all the loops' capacity is provided on copper pairs, solutions have sought to increase the amount of data/traffic that can be transmitted over a copper pair, such as xDSL technologies. Increasing data rates come at the expense of a reduction in the transmission distance; the twisted pair copper cables have to be shorter in length to the extent that active equipment (generally DSLAMs) is deployed at street cabinet locations.

There are other techniques that can offer improved services at the local loop.

- Hybrid fibre coax: This uses fibre to a primary cross connect point (PCP) and then coaxial cable to the end-user. This is e.g. used for cable-TV distribution.
- Fibre direct to the customer: Historically, this used to be limited to business customers with large line capacity requirements. However, currently, fibre connections are common place. Two network architectures may be rolled out:
    - a PTP (point to point) architecture: the fibre is deployed using a tree topology with a dedicated fibre for each customer premise.
    - a PON (passive optical network) architecture: the fibre is deployed using a tree topology but the fibres are not dedicated to a premise. The fibres are split so that several premises share the same fibre between the exchange point and the splitter.

Supporting criterion 11: The model should include both PTP and PON network architectures for FTTH networks, reflecting the actual modelled operator.

3.3.4. Degree of optimisation

Supporting criterion 12: The choice of technology and degree of optimisation is subject to the scorched-node assumption and the requirement that the modelled network as a minimum should be capable of providing comparable quality of service as currently available on the modelled operator's network, and be able to provide functionality comparable to that of the existing services.

3.4. Network demand

One of the main characteristics of Denmark's fixed telecom market is the presence of overlapping access networks owned by the infrastructure providers. For instance, TDC's copper network is present (almost) wherever and TDC has deployed cable-TV. In practice, the copper, cable-TV and the fibre networks could be seen as a parallel deployment having a shared use of civil engineering and accommodation. However, it appears that, contrary to some other European countries, FTTH, cable-TV and copper networks do not share the same trenches. This appears to be due to historical reasons since, from a technical point of view, nothing prevents the three networks to be hosted in a same trench, using different ducts, as it is the case in other countries where cable-TV, copper and FTTH networks can be hosted in same trenches.

The LRAIC approach implemented in this project aims at mimicking the level of costs in a competitive and contestable market (see section '2.1 Cost orientation methodologies available to DBA') in order to send the right build/buy signals , while ensuring that the efficiently-incurred costs of the modelled operator are adequately recovered.

As such, and while making sure the proper cost reference is taken into account for the assets that are not considered to be replicable by an access seeker (see section '2.1.3 Relevant cost standard'), each access network should support the demand of the services provided over it (including both, retail and wholesale demand), plus a reasonable security margin to account both for the preventive deployment of new equipment and the excess capacity that needs to be reserved for proper functioning.

Main criterion 8: The LRAIC model should assume that each access network technology supports its actual demand.

3.5. Network coverage costs

In the access network, not all premises have an active subscription enabling to recover the costs of the associated access line. In practice, several situations can occur. These include:

- **premises passed**, i.e. those within reach of the primary and secondary cable networks;
- **premises connected**, i.e. those to where a final drop cable has been deployed;
- **premises which have an active subscription**, i.e. those over which costs are recovered.

Rolling out a network by only deploying the network for active customers would be highly inefficient in the long run. In this regard, operators can follow different alternatives to deploy (and decommission) the drop wires and infrastructure to improve their efficiency. For instance, it is common that in buildings with several households, drop wires are deployed from the building basement to all households even if some households do not host an active customer.

As a consequence, access networks in the LRAIC model should reflect the realities of the SMP operator(s) on the deployment (and decommission) of drop wires and infrastructure, as long as the strategy followed is considered to be representative of an efficient operator.

Supporting criterion 13: The cost of passing all the premises within an area should be modelled. Drop wires should be deployed (or decommissioned) in the model based on the strategies followed by SMP operator(s), as long as these are considered to be representative of an efficient operator.

4. Types of costs and costs allocations

There are two dimensions in categorising costs when considering fixed networks:

- The first dimension categorises costs depending on how assets contribute in producing certain services (e.g. directly or indirectly).
- The second dimension deals with whether costs refer to investments to acquire physical assets (Capital expenditure, or CAPEX) or are the result of normal business operations (Operational expenditure, or OPEX). This raises the question of how to identify CAPEX and OPEX costs.

	CAPEX	OPEX
Direct costs	IPTV PLATFORM	Electricity consumption of the IPTV platform…
Indirect costs	Trenches…	Staff managing the trenches…
Overheads	IT…	CEO wage…

Illustration 4.1. Different types of costs for a telecom network and examples [Source: DBA - Final MRP (July 2013)]

4.1. Direct, common costs and Corporate Overheads

In an electronic communications network, assets are usually not used exclusively for one set of services but are instead shared between a group of services or even among an entire portfolio of services produced by an operator (e.g. trenches in fixed network). Costs can thus be categorised into two main groups: attributable and non-attributable costs. Among attributable costs, there are direct and indirect costs, whereas nonattributable costs consist of only corporate overheads. Indirect costs consist of joint and common network costs[19].

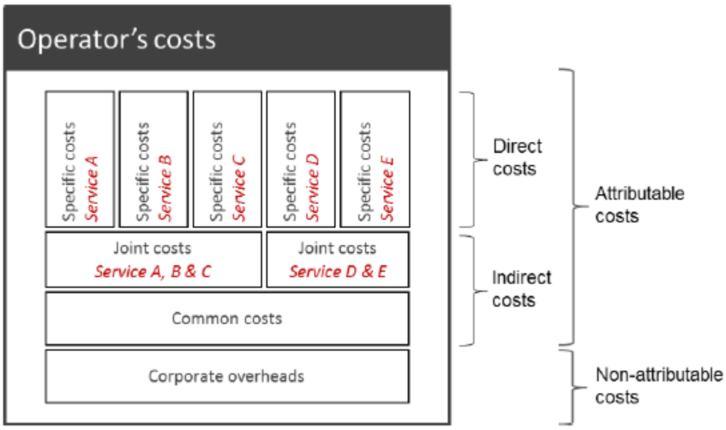

Illustration 4.2: Different types of costs in an operator's costs [Source: DBA - Final MRP (July 2013)]

The definition of each sub-group of cost is given below.

- **Direct costs:** these costs are directly related to the production of a given service. They would cease to exist if the service was to be terminated. They are therefore directly attributable costs that have an unambiguous causal relationship with the considered service
- **Joint and common network costs:** these costs cannot be specifically allocated to one service; they are incurred when producing a given set of services. They are indirectly attributable costs that have an unambiguous cause-effect relationship with the considered group of services.
- **Corporate overheads (also known as "non-network common costs"):** Overhead costs are costs that are incurred to operate a telecommunications company but that are not directly incurred to provide a core and access network. Examples include human resources, legal, and planning departments. These costs cannot be attributed in a non-arbitrary way (non-attributable costs). They are shared by the entire portfolio of services.

As a general rule, it can be considered that when an operator produces several services, it is less expensive to jointly produce these services than to produce them separately: the total cost of producing several services is lower than the sum of the stand-alone costs. Joint and common costs, therefore, consist of economies of scope achieved by an operator.

[19] Sometimes, corporate overheads are categorised also as indirect costs because by definition they are not direct costs.

When trying to assess the cost of a service, its joint and common network costs raise the question of how to allocate them among the different services produced by the operator. Joint and common costs are prevalent in telecommunications networks. Several network elements are not specific to a given service but are required to provide a set of services. The allocation of network costs between different services is a key issue for network costing because telecommunications networks support and share many services (broadband, IPTV, leased lines, etc.).

Joint and common cost allocation is a complex and critical task as different methods can lead to different unit costs for a given service. The following sections present various cost allocation approaches for the different types of costs.

4.1.1. Direct Network Costs

Direct network costs refer to those cost categories required in the network to carry the dimensioned capacity. Direct network costs in the exchange network include, but are not necessarily limited to, ports, processor cards (including software) and associated operating costs.

Supporting criterion 14: The LRAIC model will present the total direct network costs of the different network elements separately for CAPEX and OPEX.

4.1.2. Joint and network common costs

Indirect network cost categories include items such as accommodation, installation, provision of power and air-conditioning, and support systems. Ideally, these costs should be considered in the model, through the use of a "mark-up" on the direct network costs as an approximation (see section '4.3 OPEX assessment').

Installation costs can usually be provided by operators and/or manufacturers or can be derived/estimated as a percentage of the investment costs.

Support systems are likely to include equipment specific operation/management systems and also more generic network management systems. For the former, specific costs might be available either from the modelled operator (for equipment currently used by the operator) and/or from the manufacturers. For the latter, estimates might well need to be made based on systems currently in use by the modelled operator and also, perhaps, by other operators within Denmark. International benchmarking might also be useful with respect to such generic network management systems.

The costs of accommodation could be estimated in the model in two ways - the first is to use a mark-up, the second is to look at the accommodation requirements of a modelled equipment, on a number-of-square-metres basis, and the cost per square metre for such accommodation in different parts of the country. The latter approach should be adopted wherever practical to estimate the costs of accommodation.

Supporting criterion 15: The LRAIC model should consider indirect costs, such as accommodation, costs of installation, support systems, power, and cooling.

Different allocation keys can be envisaged for the allocation of joint and network common costs. The choice of the allocation can lead to very different unit costs for a given service.

In cost modelling, two types of cost allocation families are generally considered: proportional rules cost allocation families (technical allocation) or game-theory rules cost allocation families (economical allocation):

- **Proportional rules (technical allocation)**: capacity-based allocation, Moriarty, and residual benefit.
- **Game-theory rules (economic allocation):** Shapley-Shubik, nucleolus.

Each allocation rule has its advantages and drawbacks. The capacity-based allocation rule is the rule that is generally used by regulatory authorities for allocating joint and common network costs. This approach has the advantage of being more easily implementable in a bottom-up model.

In particular, the capacity-based allocation rule allocates common and joint costs to the services based on the network capacity required by each service at the busiest hour[20]. This rule is the one traditionally used by DBA as it follows the cost drivers (networks are dimensioned to support the peak of traffic). As the traditional rule, the capacity-based allocation rule should be implemented in the model.

Other alternatives based on game-theory rules suppose a more theoretical approach. The use of these alternatives is often debatable and, while they are much more complex to implement and review, they do not necessarily provide more accurate results.

Main criterion 9: Capacity-based allocation for joint and common network costs should be implemented in the LRAIC model.

[20] Period during which the maximum total traffic load occurs.

4.1.3. Corporate overheads

In addition to network costs, an operator faces non-network common costs such as the costs of maintaining a corporate office which are incurred to support all functions and activities. Examples of these costs include costs associated with corporate headquarters, senior management and internal audit.

Identifying the impact of an increment on corporate overheads is a very complex task. These costs are potentially material and should be recovered if relevant[21]. These costs should be defined according to the characteristics of each modelled operator.

According to BEREC, the method traditionally used by NRAs to allocate these costs is the EPMU approach[22]:

> *"In a regulatory environment it is accepted that all services should bear, in addition to their incremental cost, a reasonable proportion of the common costs. The preferred method of allocating common costs is Equal Proportionate Mark- Up (EPMU)."*

Under the EPMU approach, each service is allocated a share of the common costs in proportion to that service's share of total attributable costs.

[21] DBA, Article 6.2.3 of the Accounting Separation Regulation limits un-attributable cost to less than 10% of overall costs, dated 2 August 2004.

[22] EC, ERG common position: Guidelines for implementing the Commission Recommendation C (2005) 3480 on Accounting Separation & Cost Accounting Systems under the regulatory framework for electronic communications, dated 19 September 2005.

Corporate overheads cost allocation in a 3-service network (Voice, Internet, Leased Lines)

- Corporate overheads according to Top-Down: DKK 100M
- Attributable costs (i.e. direct + indirect costs):
  - Voice DKK 320 M
  - Data DKK 530 M
  - Leased Lines DKK 80 M

	Attributable costs		→		Corporate overheads	
Voice	DKK 320 M	34%		Voice	DKK 34 M	34%
Data	DKK 530 M	57%		Data	DKK 57 M	57%
Leased Lines	DKK 80 M	9%		Leased Lines	DKK 9 M	9%
					DKK 100 M	100%

Illustration 4.3. Numerical example of the EPMU method (for illustrative purpose only) [Source: DBA - Final MRP (July 2013)]

While the EPMU approach is relatively simple to implement, the main drawback of this approach is that it does not take into account efficiency considerations[23].

This approach has traditionally been used in previous LRAIC models developed in Denmark and other European countries.

Main criterion 10: Corporate overheads costs should be allocated on the basis of the EPMU approach.

4.2. CAPEX assessment

CAPEX are costs incurred when a telecom operator invests in equipment and/or designs and implements the network infrastructure. The equipment includes for example the DSLAMs, the routers, the switches, and the entire core network equipment, whereas the

[23] "Ramsey-Boiteux" is an alternative to the EPMU approach. With this approach, the size of the mark-up on each service is inversely proportional to the price elasticity of demand for that service, as this minimises the consumption-distorting effect of raising prices above marginal cost (see Laffont and Tirole, 2001, Competition in Telecommunications, Cambridge: MIT Press, for more detailed on Ramsey-Boiteux pricing). This approach tends to maximise the welfare but is rarely implemented in practice due to the difficulty to calculate price elasticities.

costs for the design and implementation of the network infrastructure can be site acquisition and civil works.

In the LRAIC model, CAPEX is derived from the service demand through engineering principles and the equipment prices.

4.2.1. Equipment Prices

Equipment prices are likely to vary between operators for a number of reasons including differences in underlying network structure, specification, business focus, bargaining power and bargaining ability. Where significant differences exist between the cost estimates provided by different operators, clarification may be needed to ensure that the estimates refer to equipment with equivalent specifications. In all cases, the source of the inputs included will be clearly referenced in the cost model.

Moreover, based on their scale, some operators could be expected to have stronger bargaining power than others. The model should take this into account and ensure a proper reconciliation with top-down figures from the modelled operator.

Main criterion 11: Prices used in the model should reflect those that an efficient operator would face, taking into account the scale of the modelled operator.

4.3. OPEX assessment

OPEX are costs incurred as a result of an operator performing its normal business operations. The OPEX to be taken into account for the LRAIC model is network driven, i.e. the costs associated with the operation of the network, transmission, site rentals, operation and maintenance.

Several methods of operating cost assessment are possible, the choice of which depends on the goal of the modeller and the availability of data.

a. **Top-down assessment**: as in the norm of top-down modelling, OPEX costs are based on the operator’s actual costs and can be obtained directly from the operator’s accounting records. This type of approach is not necessarily in line with bottom-up cost models except if the operator’s costs are efficiently defrayed;

b. **Top-down assessment with potential efficiency adjustments**: as explained earlier, top-down modelling reflects the actual costs incurred by an operator, but it can also incorporate network inefficiencies. To eliminate this problem, some efficiency adjustments can be set up. For example, in the example below, the operator costs for repairing the access network can be reduced to reflect a lower fault rate of a new entrant's more efficient network;

<u>Cost of faults:</u>

Faults OPEX (accounts – top down): DKK 10M/year

Operator figures: 15 faults/100 lines/year

Efficient operator figures: 10 faults/100 lines/year

Efficiency gain: -33% (15 faults vs. 10 faults)

Faults OPEX = DKK 10M x (1-33%) = DKK 6,7M/year

Illustration 4.4. Numerical example of top-down assessment with efficiency adjustments (for illustrative purpose only)

c. **Bottom-up assessment (based on a percentage of capital cost)**: This approach uses percentages provided by suppliers of telecom electronic equipment[24]. The suppliers often provide estimates of the annual operating costs expressed as a percentage of the investment. It can also correspond to direct vendor support contracts.

d. **Bottom-up assessment (based on necessary employees)**: operating costs are determined based on the number of necessary employees that evolves with the corresponding cost driver.

<u>Access infrastructure management:</u>

Minimum staff: 10 FTE

+1 FTE per 2 MPEG stations

30 Mpeg stations

Total staff = 10 + 30/2 = 25 FTE

Staff cost = DKK 500,000 per FTE

Access infrastructure management OPEX =

DKK 500,000 x 25 = DKK 12,5 M/year

[24] For example, in a public consultation, the Irish NRA ComReg has considered that the annual operating costs related to DSLAMs are equal to 10% of the investment (see ComReg, Wholesale Broadband Access Consultation and draft decision on the appropriate price control Document No: 10/56).

e. **True bottom-up assessment:** this approach consists in calculating the network's requirements (in energy, cooling, square meters) and to conduct a bottom up assessment of OPEX (e.g. energy cost = kWh requirement for all networks elements x kWh price);

f. **Benchmarking**: this way of assessment involves collecting and analysing OPEX mark-ups used by NRAs in other comparable countries.

Approaches b, c, d and e tend to model the efficient costs of an operator. However, approaches b, d and e rely on many assumptions that are challenging to predict accurately (e.g. staff needed to maintain the network element, efficiency gain, etc.). The DBA/Axon team believes that alternative c, bottom-up assessment (based on a percentage of capital cost), is the best option because:

1. It strikes a reasonable balance between accuracy, the number of assumptions required and comparability against international references.
2. Provides easy reviewing mechanisms (i.e. there is broad consensus in the industry on the common range OpEx should represented over CapEx)
3. Ensures consistency with the approach generally used in the current version of DBA's fixed LRAIC model.

However, in the event that operators are able to provide more accurate estimations of the absolute yearly operational costs associated to each network element, the model will consider these estimations from the operators.

Further, for operating expenditures requiring man-work, the model will consider a productivity gain, indicating that each year the same task can be made more efficiently compared to the previous year.

Main criterion 12: Operating costs for each network element should be calculated using a bottom-up assessment based on a percentage of capital cost, unless the operators can provide accurate estimations on the absolute yearly operational costs of each network element.

4.4. Depreciation Methodologies

An important element of a LRAIC model is the estimation of the annual cost associated with assets. Annuities measure both the depreciation charge and the capital charge associated to the assets.

An annuity is the annual payment which, when discounted at an appropriate cost of capital and summed over the asset lifetime, gives the replacement cost for an asset. The alternative approach sometimes used is economic depreciation. This involves measuring the depreciation charge as the annual change in the net present value (NPV) of an asset, adjusted for factors such as changes in output profile or prices, overhead cost and the cost of capital

Three traditional annuities formulas will be presented in this section: the standard annuity (4.4.1), the tilted annuity (4.4.2)and the full economic depreciation (4.4.3).

4.4.1. Standard Annuity

The use of this method is appropriate when asset prices and volumes of outputs produced by an asset are stable. The standard annuity approach consists of calculating an annual charge A called annuity, which is identical every year and which respects the following equation:

$$I = \frac{A}{(1+\omega)} + \frac{A}{(1+\omega)^2} + \cdots + \frac{A}{(1+\omega)^n}$$

Then, A can be written as follows:[25]

$$A = I \times \frac{\omega}{1 - \left(\frac{1}{1+\omega}\right)^n}$$

where ω is the cost of capital, I the investment, n the asset life.

[25] This formula assumes that the operator begins generating revenues from the asset one year after investment is completed.

The standard annuity approach calculates an increasing depreciation charge and a decreasing return on capital employed in such a way that the annuity remains stable over time.

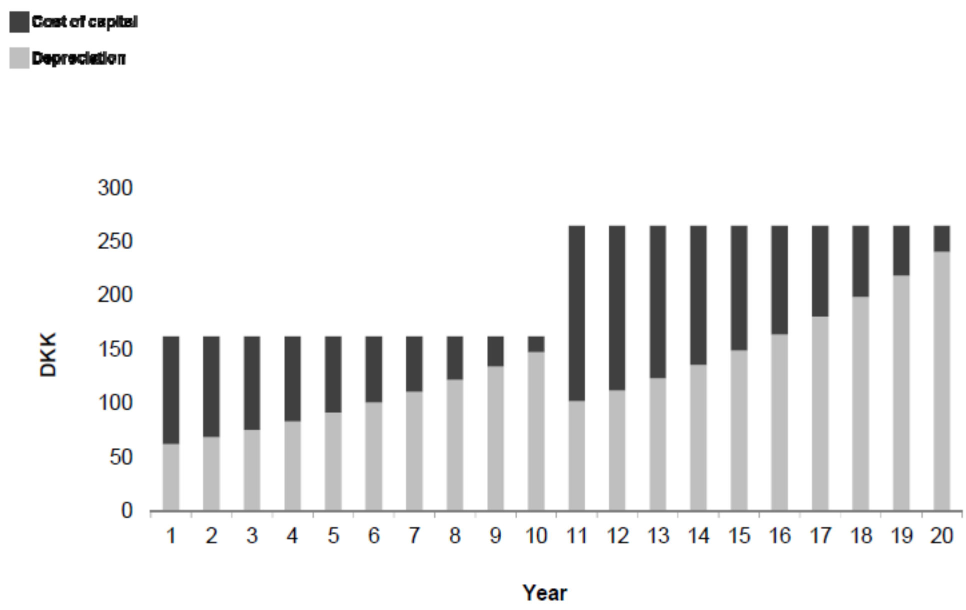

Illustration 4.5. Asset renewal (year 11) at a higher price under standard annuity method (discontinuity) [Source: DBA - Final MRP (July 2013)]

4.4.2. Tilted annuity

The tilted annuity formula is probably the most widespread depreciation formula used for regulatory purposes. It incorporates a tilt which enables the calculation of annuities that evolve in line with asset price changes: if an asset price increases by say 5% per annum, annuities will also increase by 5% per annum, as illustrated in Illustration 4.6.

Such a formula sends appropriate 'build or buy' signals to market players. It also allows replicating the annual charges that would be faced by an operator in a competitive market.

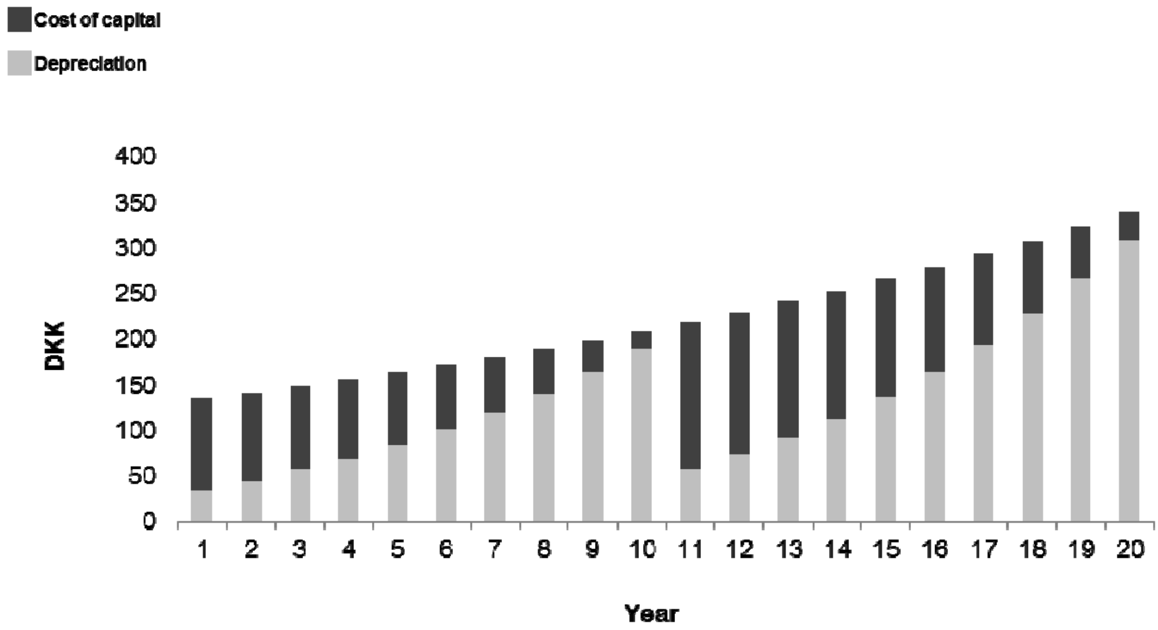

Illustration 4.6. Annuities with the tilted annuity method - Asset renewal (year 11) under tilted annuity method – Asset price increase of 5% per annum (continuity) [Source: DBA - Final MRP (July 2013)]

A tilted annuity can be calculated on the basis of the following formula:

$$A_t = p_t \times \frac{\sum_{j=1}^{n}(1+\omega)^{\mathrm{j}} \times I_j}{\sum_{j=1}^{n}(1+\omega)^{\mathrm{j}} \times p_j}$$

This can be written as follows:

$$A_t = I \times \frac{(\omega - p) \times (1+p)^t}{1 - \left(\frac{1+p}{1+\omega}\right)^n}$$

Where ω is the cost of capital, I the investment, t the year considered, n the asset life, p the tilt (price trend of the asset in the long term) and A_t the annuity of year t[26].This formula is derived by the same equation as the one provided in the beginning of this section[27] but with the following relationship between each annuity:

[26] This annuity is calculated by assuming that the first annual cost recovery is happening one year after the investment is made. If the time between the moment the first annuity happens, and the investment is paid is one year lower (respectively one year higher), then the annuity should be multiplied by a $(1+\omega)^{-1}$ (respectively $((1+\omega))$.

[27] $I = \sum_{i=1}^{n} \frac{A_i}{(1+\omega)^i}$

$$A_t = A_{t-1} \times (1 + p)$$

which means that annuities are evolving with asset prices.

Even more important, tilted annuities allow a smooth evolution of annual cost despite price changes and investment cycles. At the end of the useful life of an asset, i.e. when the asset needs to be renewed, the annuities calculated with the tilted annuity method will be similar just before and just after the renewal of the asset (as shown in the illustration above). Therefore, annuities evolve without the discontinuities which are one of the main drawbacks of the standard annuity approach. If the volume of output produced by an asset is stable, then the tilted annuity is a good approximation for economic depreciation.

However, the tilted annuity may not be a good proxy for economic depreciation when the volume of outputs produced by an asset is not stable. This may be the case for new services (which have a logistic curve) or when demand is evolving fast (see example below).

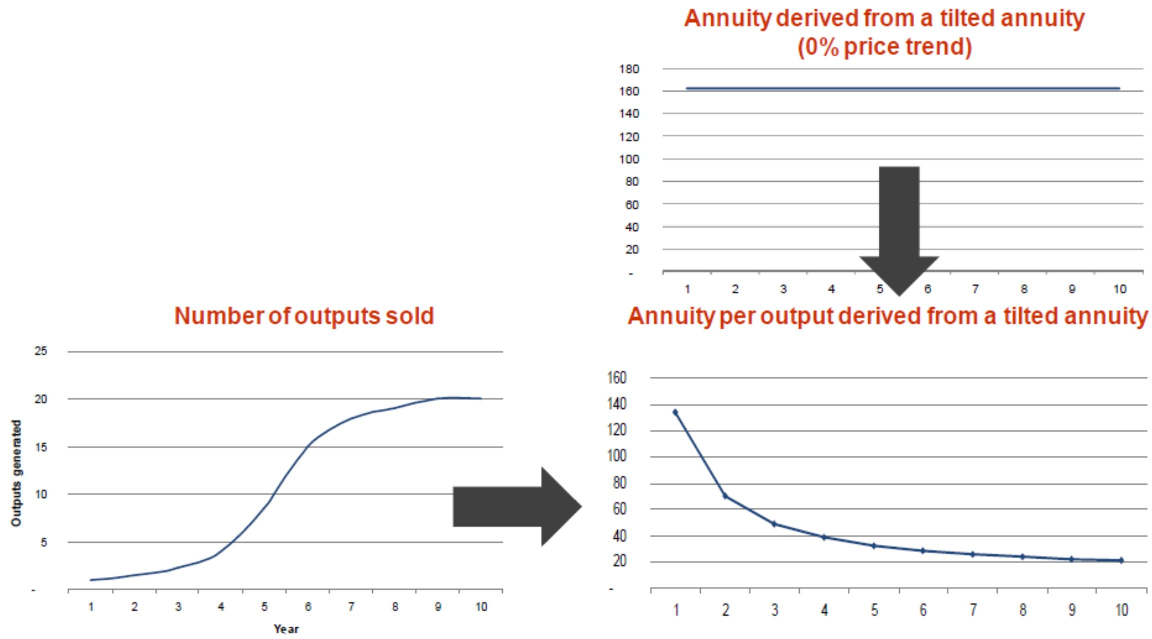

Illustration 4.7. Example of unit cost derived on the basis of the tilted annuity formula when the number of output produced by an asset is increasing [Source: DBA - Final MRP (July 2013)]

In this case, a full economic depreciation method can be used.

4.4.3. Full economic depreciation

It is possible to modify the tilted annuity formula to compute annuities that take into account the evolution of the number of outputs produced by assets. This is referred to as a “full economic depreciation”. The same formula as the tilted annuity one is used, except that additional parameters are considered in order to ensure the annuity varies in the same way as the number of outputs.

The annual cost can be computed as follows:

$$A_t = O_t \times p_t \times \frac{\sum_{j=1}^{n}(1+\omega)^{\mathrm{j}} \times I_j}{\sum_{j=1}^{n}(1+\omega)^{\mathrm{j}} \times O_j \times p_j}$$

Where,

- A_t represents the annual depreciation cost
- O_t is the production factor of the asset in year t
- p_t is the reference price of the asset in year t
- ω represents the cost of capital
- I_j represents the yearly investment, calculated as the number of assets purchased in year j multiplied by their unit price in that year
- N represents the last year in which an asset is used in the network

The annuity varies here with the number of outputs produced by the assets and with the price trend. When the asset produces a low number of outputs (for example, FTTH in early years when there are few customers), then the annuity is low at first then increases when the number of outputs produced increases (for example, FTTH penetration rate increases).

The illustration below illustrates the full economic depreciation method (without taking into account evolution of asset prices) with which the unit cost per output is stable.

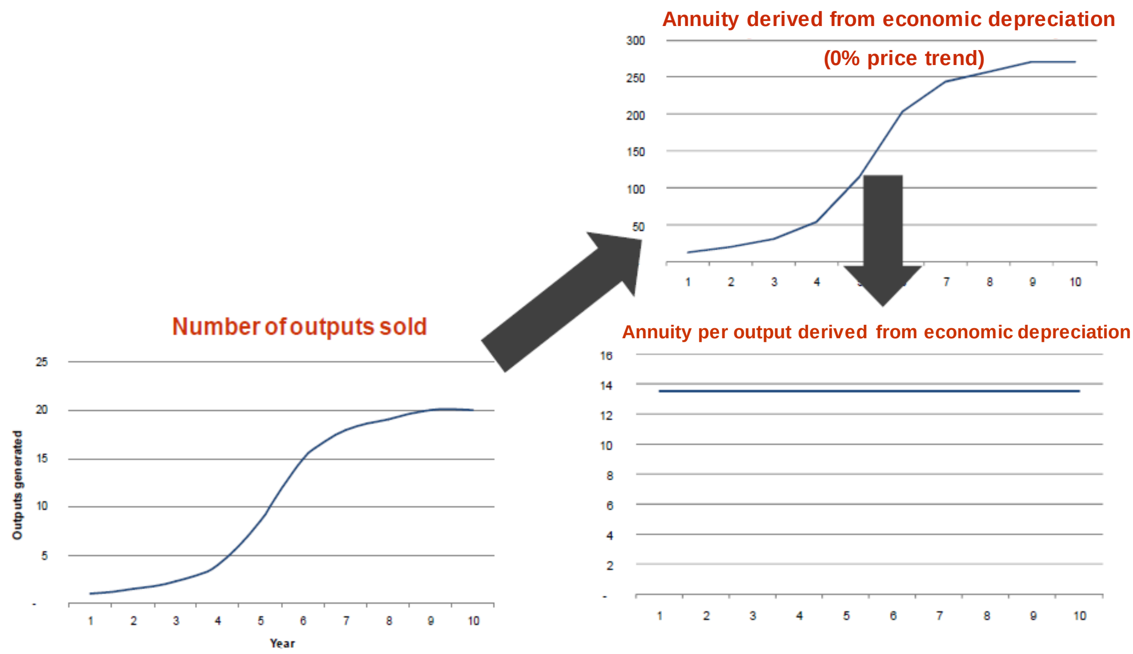

Illustration 4.8. Annuities (depreciation charges plus return on capital employed) under the full economic depreciation method [Source: DBA - Final MRP (July 2013)]

By taking into account changes in output, annuities reflect changes in the market value of the asset, which corresponds to the definition of economic depreciation. With such a full economic depreciation, the annuity per output remains stable and follows the evolution of asset prices.

The main drawback of this depreciation method is that it requires forecasts on the outputs produced over a long period of time. As a consequence, it is more subjective than other methods (even if the tilted annuity method is also somewhat subjective in setting long term price trends). Finally, it is a more complex method to implement. However, it tends to give better economic signals than other depreciation methods when the number of outputs produced by an asset is not stable.

Main criterion 13: Tilted annuities and full economic depreciation should be implemented in the LRAIC model.

4.5. Cost of Capital

When an operator invests in an asset, it must be able to recover the appropriate costs of financing this investment: on the one hand, it supports the cost of equity as measured by the returns that shareholders require for this investment and on the other hand, it supports the cost of debt if the investment is also financed by debt. In regulation, these financial costs are typically recovered through the use of a "weighted average cost of capital" ("WACC"). The cost of capital reflects the opportunity cost of funds invested in the asset, and is incorporated into the cost model by multiplying the WACC by the capital employed or through the application of an annuity formula which combines the calculation of both the return on capital and the depreciation charge.

WACC values to be considered in the model shall be based on the latest decisions published by DBA.

Main criterion 14: WACC values considered in the cost model should be aligned with the up to date decisions determined by DBA.

Further, as detailed by the EC in the EECC,

> *"Where the national regulatory authorities consider price control obligations to be appropriate, they shall allow the undertaking a reasonable rate of return on adequate capital employed, taking into account any risks specific to a particular new investment network project."*

Therefore, if deemed appropriate, an NGA premium may be considered under specific circumstances to account for risks specifics to particular investments.

Supporting criterion 16: The LRAIC model should have the possibility of including a risk premium for NGA/VHCN networks.

4.6. The cost of working capital

The activity of an electronic communications operator requires or generates cash for everyday operations: this amount of cash is defined as "working capital". The working capital is calculated as the WACC times the difference between current assets minus current liabilities. Working capital may either be positive (i.e. generate a cost) or negative (i.e. generate revenues), depending on the financial situation of the operator.

Based on an assessment of the working capital situation of the current SMP operator in Denmark, we have concluded that there is not a clear cost of working capital associated to the provision of the services to be included in the cost model. In particular, not even the likely sign of the working capital is known (i.e. whether it could represent a cost or a revenue to the modelled operator). Therefore, given the uncertainties surrounding this input, and the unlikelihood of getting access to detailed financial information to accurately assess working capital, a conservative approach consisting of not including working capital in the model is preferred.

However, if the modelled operator quantitatively proves the existence of working capital, then it will be left empty (set to 0) in the model. The model will at all times include the functionality to consider working capital.

Supporting criterion 17: The LRAIC model should include the functionality to consider working capital. However, unless the modelled operator quantitatively proves its existence, it will be left empty (i.e. no working capital will be considered).

5. Model implementation

The bottom-up model should produce LRAIC estimates for exchange of data traffic, access lines and ancillary services (such as activation, co-location and interconnection points) subject to the scorched node assumption. It incorporates a set of general assumptions, particular inputs and intermediate and final outputs linked with each other through the use of formulae based on specific engineering, economic and accounting principles.

The basic structure of the model can be summarised by the following steps:

- Service Demand
- Network Demand
- Network hierarchy
- Network dimensioning
- Costing the Network
- Allocation of costs to services

Further, this section includes a special sub-section dedicated to Co-location services.

5.1. Service Demand

The main source of information on the current level of demand in Denmark will be the fixed network operators. The model will include the demand for the services listed in section '3.2 Services', which includes wholesale and retail services. .

Supporting criterion 18: The starting point when building the bottom-up model is the level of demand in Denmark for all the modelled services.

The demand for each modelled service will be introduced from the starting year until the final year considered in the model (from 2005 until 2038, or otherwise concluded based on data availability) in the corresponding units (e.g. lines for access services or Mbps for bitstream capacity services).

In order to define the demand inputs until 2038, forecasts will be requested from operators which will be complemented by a regression analysis based on historical trends to be performed by the DBA.

Supporting criterion 19: The LRAIC model will include demand forecasts until 2038 (or earlier if otherwise concluded based on data availability) for the modelled services.

The following paragraphs describe the approach to be adopted with regards to the definition of the demand inputs for each of the key categories of services to be modelled:

- Broadband and TV services
- Leased Lines
- Access services

5.1.1. Broadband and TV services

As a minimum, the model should be able to identify the number of customers for each of the major broadband service speeds.

Supporting criterion 20: The LRAIC model should have the capability to be able to show the demand for each major broadband service speed in terms of the number of customers.

Further, demand for other services that run over the IP network, such as multicast IPTV or Video on Demand, should also be considered in terms of number of customers and/or services provided (e.g. number of TV channels).

Supporting criterion 21: Demand for TV services such as Multicast-IPTV and Video On Demand should be included in the model.

5.1.2. Leased Lines

The model should show the total demand of leased lines circuits in terms of number of circuits by capacity bandwidths.

The use of the core network by leased lines is likely to vary significantly across the network as leased lines are more likely to be requested either within or between large towns and cities and less likely within/between small towns and villages. Thus, information should be sought on how the amount of leased line capacity sold varies across the different regions of the country and by hierarchical level within the network.

Supporting criterion 22: The LRAIC model should show the demand of number of leased lines by volume and bandwidth. Information should be sought on how the amount of leased line capacity sold varies across the different regions of the country and by hierarchical level within the network.

5.1.3. Access services

Demand of access services will include the number of active access lines associated to each technology. These lines will be disaggregated for the different services presented in section '3.2 Services'.

5.2. Network Demand

Once the service demand has been specified, the model will need to express it in network terms to properly run the dimensioning algorithms.

The conversion of demand at service level to network level involves the following relevant considerations:

- Demand drivers
- Busy hour information
- Adjustments for the grade of service

5.2.1. The calculation of demand drivers

Service demand is insufficient to dimension the network because traffic will flow through the network in different ways and thus some network elements will be utilized more than others for the same service demand.

Further, demand from the different services may be considered in different units. Therefore, in order to perform an accurate dimensioning process, the service demand must be converted to a common driver (e.g. Mbps).

There are two main ways which may be used in order to assess how end-user demand results in specific network element demand across the network:

- Demand on a route by route basis. This consists of estimating the traffic flowing over the network on a route by route basis. The amount of traffic originating from each node of the network is computed aggregating the amount of traffic from all the lines directly or indirectly connected to that node.

- Usage factors. Usage factors are defined as the average frequency that a particular service uses a given network element.

DBA recommends that usage factors are used as the default method to distribute the forward-looking level of demand over the different parts of the network. Route-by-route demand might be more suitable in certain cases, for example with regard to high speed leased lines.

Supporting criterion 23: The usage factors used for the determination of the demand drivers in the model need to be consistent with the underlying network architecture.

5.2.2. Busy hour information

Although information on traffic is generally collected on an annual basis, the network will need to be dimensioned to carry the traffic flowing in the "busy hour" subject to required blocking margins ("busy-hour" traffic). The LRAIC model will need to take account of demand on different days of the week and in different months of the year, but not traffic surges caused by special events such New Year's Eve. It should be noted that "busy-hour" can vary in different parts of the network and for different services (for example, broadband usage). This will be captured in the model by considering that the capacity required by each service is equal to the contribution of each service to the total network busy hour.

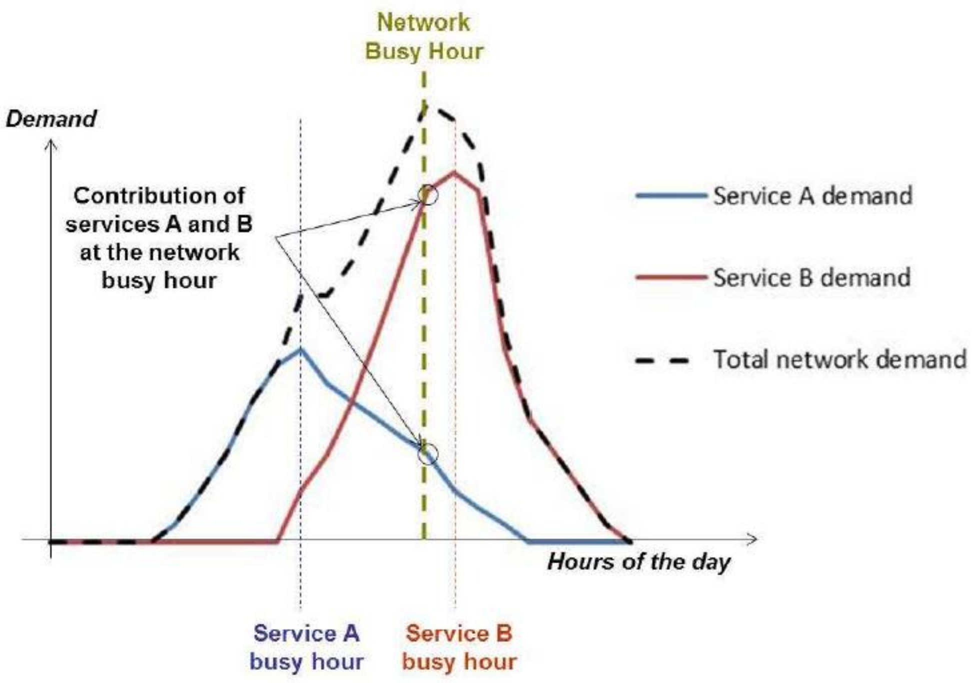

Illustration 5.1. Busy hours occur at different times of the day for the different services [Source: DBA - Final MRP (July 2013)]

Information on the busy hour will need to be sourced from the operators for all relevant services.

For non-contended services, such as leased lines, the full capacity should be assumed to be used even though in practice the customer is unlikely to utilise that capacity on a 24/7 basis.

Supporting criterion 24: The LRAIC model should clearly identify busy-hour information for all relevant traffic. The LRAIC model should also be flexible enough to allow for changes in these figures. Information on the busy hour will need to be sourced from the operators for all relevant services.

5.2.3. Adjustments for the grade of service

For real-time traffic flowing over the IP network, additional adjustments are likely to be necessary to take account of the need to prioritise such traffic as it flows across the network.

The LRAIC model should demonstrate that the modelled network provides services at an appropriate level of quality for an efficient modelled operator, particularly for real time traffic (such as VoIP and IPTV) and non-contended ("leased lines') traffic.

Supporting criterion 25: The LRAIC model should demonstrate that the modelled network provides services at an appropriate level of quality for an efficient modelled operator, particularly for real time traffic (such as IPTV) and non-contended ("leased lines") traffic.

5.3. Network hierarchy

5.3.1. The Scorched Node Assumption

DBA interprets the Scorched Node constraint such that when modelling an "optimally structured network" under the scorched node assumption the locations for equipment are constrained by the existing number of sites and their existing locations. However, the scorched node assumption does not imply that the transport network - cables, duct/trench etc. - is fixed. Nor does the assumption imply that the same number and type of equipment should be placed at each of these geographical locations.

Supporting criterion 26: The LRAIC model should show the costs of a network with an efficient configuration operated by an efficient company, based on the latest proven technological solutions and an optimally structured organisation. However, the starting point should be the existing geographic network architecture in the modelled operator's network. This implies that equipment should be placed at the existing geographical locations of the modelled operator's network nodes (the scorched node assumption).

The following list of equipment meets for example the basic definition of a node within an all-IP network[28]:

- A DSLAM/OLT/CMTS;
- A Layer 2 Ethernet switch; and
- A Layer 3 IP router.

Whatever type of node is used, the boundary between the core and access networks will remain at the line card situated at the relevant exchange, with the line card included in the costs of the access network.

5.3.2. The Hierarchy of the "*Exchanges*"

The LRAIC model is to adopt an "all-IP" network. Although such networks are often thought of as comprising a mesh-like structure, such that packets can find lots of ways through the network, in practice an operator will still organise the network using a hierarchical approach.

A typical four-layer hierarchy might comprise the following layers:

- Core Routers. These represent the highest level of IP routing within the network and again would typically be installed in a ring (or more likely two rings) configuration with a number of Distribution Routers feeding into two (for dual parenting reasons) Core Routers.
- Distribution Routers. These represent the second level of IP routing within the network and would typically be installed in rings, with a number of Aggregation routers feeding into two (for dual parenting reasons) Distribution Routers on a ring.
- Aggregation Routers. These are routers, used to group together a number of DSLAMs/OLTs/cable-TV equipment and also to form high capacity rings or chains in dense (typically business) urban areas.

[28] For the core network only

- DSLAMs or other access equipment (such as OLTs). The DSLAMs represent the layer at which the customer typically connects (via a DSLAM line card). Within a Next Generation Network, the DSLAMs are commonly referred to as MSANs (Multi-Service Access Nodes). These nodes are sometimes installed in a ring or chain topology to the Aggregation routers.

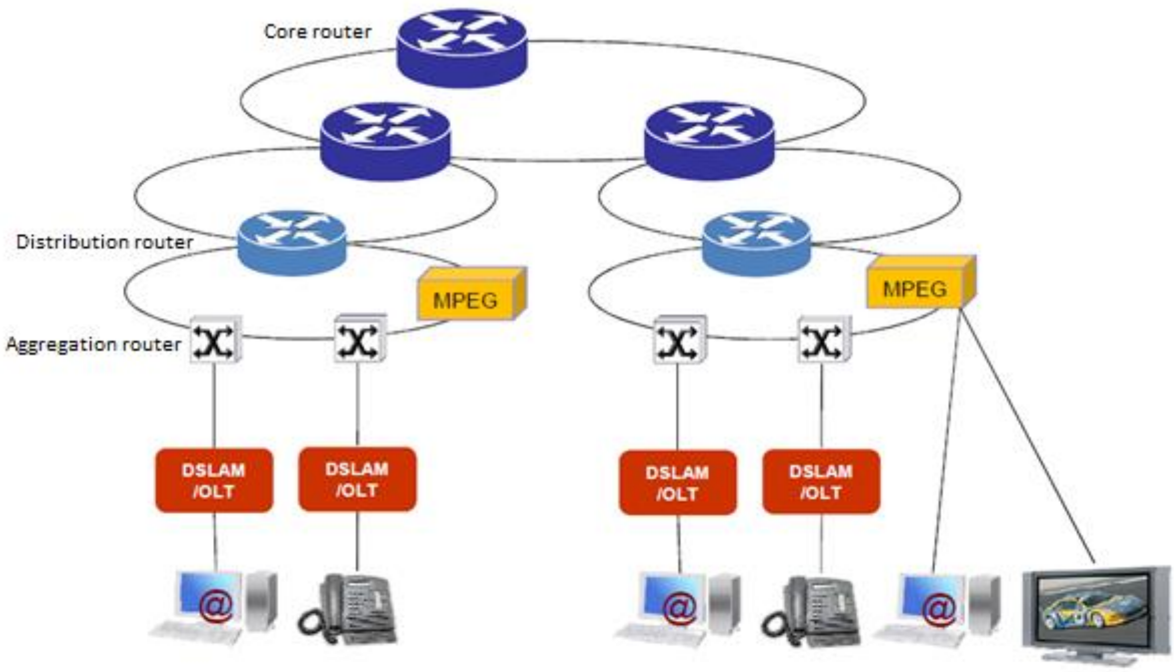

Illustration 5.2. Exchanges four-layer hierarchy (for illustrative purposes) [Source: DBA - Final MRP (July 2013)]

Supporting criterion 27: The hierarchy of the exchanges adopted in the LRAIC model should be kept unchanged. The use of DSL cards instead of POTS cards should be modelled.

5.3.2.1. The highest layer of the "exchanges"

The first step in the modelling process will be to model the top layer of the exchanges in the core network, which in an IP network would typically represent the Core Routers.

There are several ways to determine the number of nodes in this layer of the hierarchy.

- The number of core routers in the modelled operator's network.
- The calculated peak traffic needs and how this might impact the size of the equipment for differing numbers of highest level nodes. If too few nodes are chosen, then the peak traffic levels might mean that multiple core routers will need to be sited at the same location. If this occurs, then it might be more resilient to locate the equipment at multiple sites.

- International experience, the experience of other operators within Denmark, and the need for highest level interconnect could also be used to help determine the appropriate number and size of these "highest level" core router sites.

5.3.2.2. The other layers of the hierarchy

Once the number of sites at the highest layer of the hierarchy has been estimated, the remaining sites will need to be allocated to the other layers of the hierarchy. Similar analysis needs to be carried out as for the highest level in the hierarchy (see the above bullets).

In addition, the final choice might need to take account of:

- cost: the cost of serving a certain threshold of customers. The cost will need to include not only the cost of the equipment, but also other costs such as installation, operating costs, accommodation, and power and network management.
- impact on other parts of the network: the LRAIC model should be able to show the cost implications of the chosen mix on other parts of the network, e.g. transmission equipment, fibre or trenching.
- security: the implications on the quality of service should also be taken into account. For example, the ability of the network to cope with the breakdown of equipment located at one site.
- practicability: the chosen mix must be technically feasible. This means that the equipment must be able to handle the increasing amount of traffic and there must be sufficient higher level nodes to host in an effective manner all of the DSLAMs/MSANs. It also means that the distances between interconnected equipment must take account of the maximum distances for un-repeated fibre optic communications and thus the need to include repeaters on long distance routes.
- consistency with the evolution of electronic communications networks: the optimised sites must be consistent with the general evolution of network design in Denmark and around the world. That is, it must be flexible enough to allow for developments such as the growth of the Internet and moves to unbundled subloops.

Supporting criterion 28: The hierarchical design adopted in the LRAIC model considers the following factors: cost, the impact on other parts of the network, security, technical feasibility, and consistency with the evolution of the telecoms networks.

5.4. Network dimensioning

5.4.1. Modelling tools

Cost assessments in fixed networks, particularly in their access segment, are heavily influenced by the civil infrastructure needs. It is, therefore, key to rely on accurate dimensioning tools to ensure that these network assets are precisely dimensioned based on the specific location of the households as well as the modelled operator's nodes.

To achieve this objective, a database software for static calculations related to the geographical analyses will be developed. As described in section '5.4.2.3 Access network dimensioning', the access segment should be modelled at the section level (i.e. portion of a road located in between two road crossroads). For a country the size of Denmark, it is expected to have several hundred thousands of sections. A database of this size cannot be recorded in an Excel file. This is why DBA intends to use similarly to the current model, a database software to handle these calculations. However, to facilitate the understanding of the costing of the network, Microsoft Excel will be used for all other purposes (e.g. to cost the network and to calculate the results).

Supporting criterion 29: The LRAIC cost model will be based on a database software and Microsoft Excel. The usage of database solutions will be limited to the geographical assessment of the access network to facilitate the review and understanding of the LRAIC model by stakeholders.

5.4.2. Access network

Equipping the access network consists in assessing the type of equipment and the quantity that should be rolled out. This should be carried out through three main phases:

- Geomarketing data;
- Roll-out of the network
- Access dimensioning.

These phases are described in the sections hereafter.

5.4.2.1. Geomarketing data

Geomarketing data are topographical and demographical data. These are specific to each country.

It is first necessary to locate the nodes of the different access networks following the scorched node approach using the X;Y geographic coordinates of the modelled operator. These nodes are:

- The MDFs for the copper access network;
- The ODFs for the FTTH access network;
- The MPEG stations, or equivalent demarcation points for DOCSIS 3.1 networks (if applicable) for the cable-TV access network.

To each node is associated a coverage area. The coverage area is the area in which all the buildings are connected to the corresponding network node. The preferred source of information for the consideration of these areas will be geographical sources from the modelled operator. In the event that this information is not available from the operators, the coverage areas should be based on a theoretical split of the country (still using the nodes of the operators) using the Voronoi decomposition. This approach, while theoretical, closely resembles the realities that would be faced by a generic efficient operator. The Voronoi approach, should be adjusted in order to make sure there is no standalone street in any coverage area (the road network in each Voronoi area should be a convex network). The Voronoi decomposition should therefore be computed using the distance based on the road network (i.e. the distance between two points should be the sum of the lengths of the road sections located in-between the two points and following the shortest path) instead of the crow-fly distance[29].

[29] This adjusted Voronoi decomposition is consistent with reality as the access network cables tend to follow the road network.

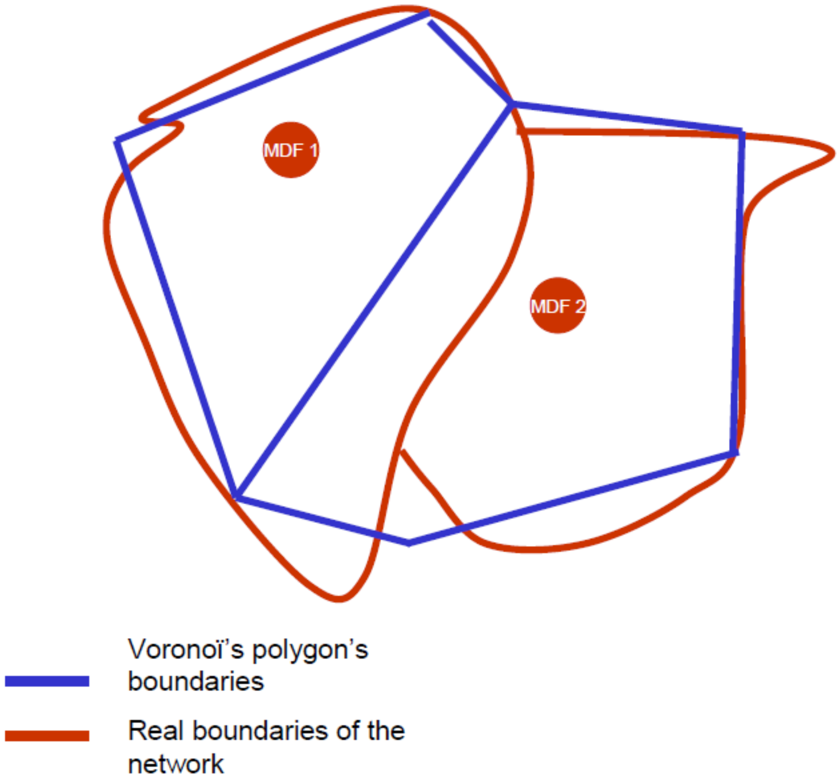

Illustration 5.3. Comparison of 2 MDF coverage areas with 2 different methods: 1) real MDF coverage area (incumbent) and 2) MDF coverage area obtained with Voronoi decomposition [Source: DBA - Final MRP (July 2013)]

To the greatest possible extent locations of sub-nodes and corresponding coverage areas of the operators should be kept in the LRAIC model. These sub-nodes are:

- The Primary Distribution Points and the Secondary Distribution Points in the copper network;
- The Distribution Nodes, the Primary Distribution Points and the Secondary Distribution Points in the fibre network; As the model will consider an increasing fibre coverage footprint, in the areas that are not currently covered by the existing access nodes, additional nodes will be installed based on a) the existing copper footprint and b) any required adjustments to reflect the differences in the average coverage area of copper and fibre nodes.
- The Primary Access Points, the Island Nodes and the Last Amplifiers in the cable-TV network.

Similarly to the previous project, SDP locations will be modelled on a bottom-up basis combining information from operators with building information from the Danish Address Register (DAR) database. This database comprises information regarding the location of all addresses in Denmark.

Main criterion 15: The LRAIC model should use as much as possible locations (X;Y geographic coordinates) of each network node of the operators.

The coverage areas should be based on the area where the relevant operators have rolled out their network.

Main criterion 16: The model should use the coverage areas of the modelled operator.

Knowing that electronic communications networks follow streets/roads (contrary to electric networks that can sometimes cross fields and roads to reach a point with a minimal distance), the second type of data necessary is data concerning the road/street network.

The road network data should be collected from official agencies, such as the DAR. More precisely, it is the network of road sections that should be the level of granularity used for the modelling as this level enables to dimension all the network elements without the need of any projection.

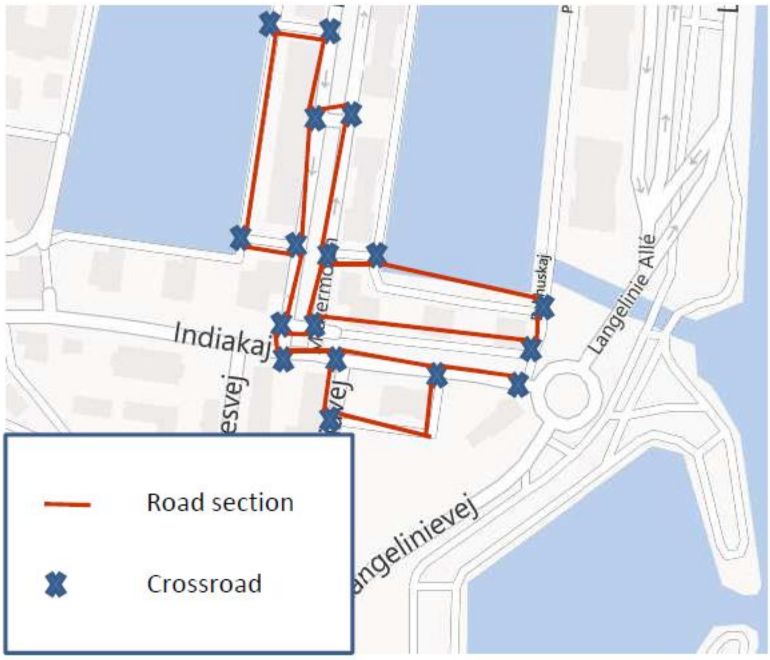

Illustration 5.4. Example of road sections (all are not highlighted in red) in Copenhagen [Source: DBA - Final MRP (July 2013)]

Supporting criterion 30: The LRAIC model should use the road network database provided by the DAR.

Data concerning buildings that have an access connection is necessary in order to be able to dimension the network. These data should include building locations and number of households per building.

The location of buildings is used to find out where the access network should be rolled out. The number of households per building allows an accurate dimensioning of the different elements of the access network as the trench sizes are derived from the cable sizes which are derived directly from the total number of households.

The building data should be collected from DAR databases. Similar sources were used in the previous revision of the LRAIC model.

Supporting criterion 31: The LRAIC model should use the data on buildings provided by DAR or equivalent sources if not available.

5.4.2.2. Roll-out of the network

The network deployment is carried out according to the operators' network architecture:

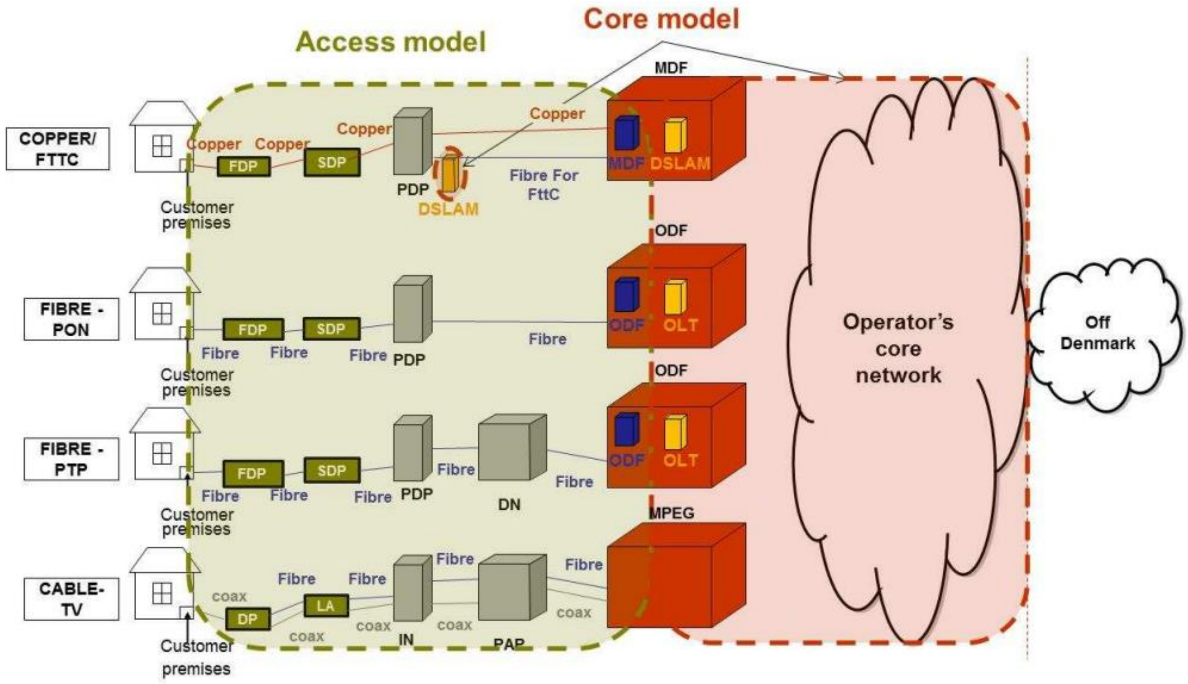

Illustration 5.5. Networks architecture (for illustrative purpose)[30] [Source: DBA - Final MRP (July 2013)]

The access copper network is made of four parts:

- The part between the MDF and the PDP (Primary Distribution Point) called "E-Side";
- The part between the PDP and the SDP (Secondary Distribution Point) called "D-Side";

[30] The cable-TV architecture shown in the figure is a typical architecture nevertheless other network architectures exist that should be taken into account when modeling the cable-TV access network.

- The part between the SDP and the FDP (Final Distribution Point) is also part of the "D-Side";
- The part between the FDP and the customer premises called "final drop".

The FTTC network is following the same architecture as the copper network, the only difference being a fibre cable is rolled out on the E-Side of the network instead of a copper cable.

There are two configurations for the FTTH access network:

- A point-to-point architecture (PTP);
- A point-to-point architecture (PON).

The PTP network is made of four parts:

- The part between the ODF and the PDP (Primary Distribution Point);
- The part between the PDP and the SDP (Secondary Distribution Point);
- The part between the SDP and the FDP (Final Distribution Point);
- The part between the FDP and the customer premises called "final drop".

The PON network is made of four parts:

- The part between the ODF and the PDP (Primary Distribution Point);
- The part between the PDP and the SDP (Secondary Distribution Point);
- The part between the SDP and the FDP (Final Distribution Point);
- The part between the FDP and the customer premises called "final drop".

The cable-TV network is made of five parts:

- The part between the MPEG station[31] and the PAP (Primary Access Network);
- The part between the PAP and the IN (Island Node);
- The part between the IN and the LA (Last Amplifier);
- The part between the LA and the DP (Distribution Point);
- The part between the LA and the customer premises called "final drop".

[31] Or equivalent demarcation point for DOCSIS 3.1 networks

Supporting criterion 32: The LRAIC model should use the operators' networks hierarchies. However, as regards fibre access network, PTP should be modelled with the same hierarchy as other access networks.

The network roll out is carried out by first connecting the main node to the primary subnodes which are then if possible connected to the secondary sub-nodes and then subsequently to buildings.

For example, the copper network is made of three parts as explained above. The MDFs are first connected to each Primary Distribution Points located in their coverage area. Then the Primary Distribution Points are then connected to each Secondary Distribution Points located in their coverage areas. Finally, the Secondary Distribution Points are connected (via FDPs) to the buildings located in their coverage areas. Possibly, depending on operators' rules, some buildings may be directly connected to the MDFs or to the Primary Distribution Points.

For each part of the network, it is possible to determine the exact shortest path (among all paths following the road network). This shortest path should be the network path.

Determining this shortest path is carried out by the "shortest path algorithm".

It is to be noted that shortest paths calculations are conducted on a "per road section basis". It is assumed that the FDP will be located in the same road section as the buildings it connects (this should be the case in the vast majority of cases). As a consequence, the "FDP-building" path does not require a shortest path calculation to be performed but rather an assumption on the distance of this link.

Supporting criterion 33: The LRAIC model should use the "shortest path algorithm" to connect two nodes together by following the real Danish road and street network.

For illustrative purpose, the illustration below represents a node area (in blue) of an access network with two street cabinets (two sub-nodes), purple and red, corresponding to three groups of buildings. This network is thus made of two parts:

- The part between the node and the street cabinet;

- The part between the street cabinet and the building.

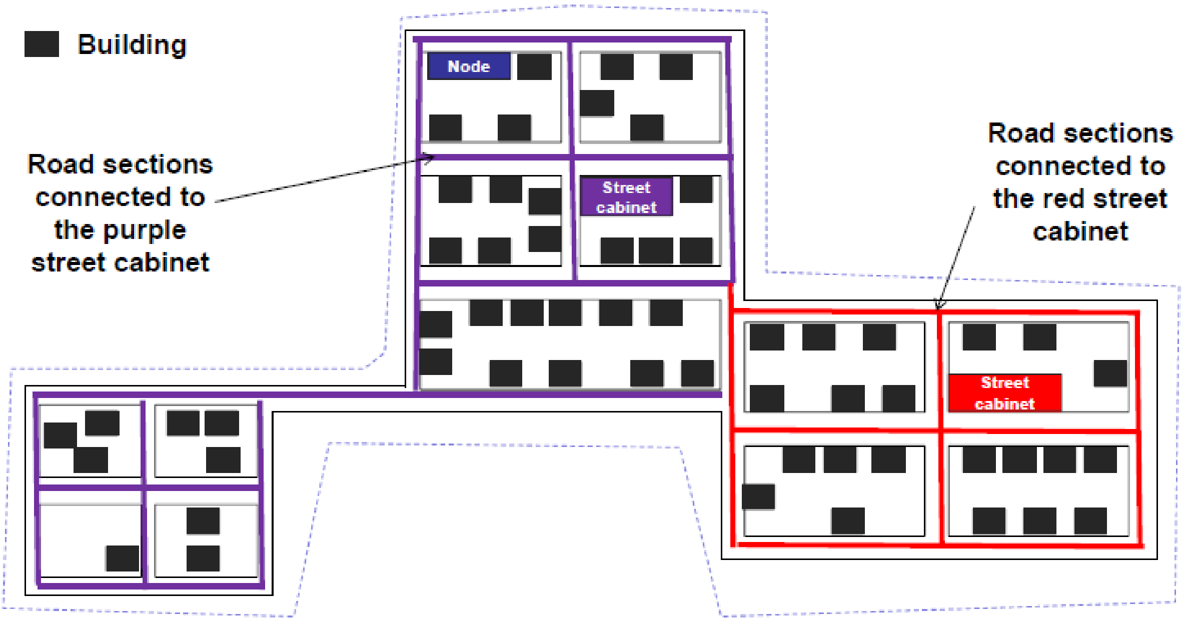

Illustration 5.6. A node area and the shortest path possible between street cabinets and building groups [Source: DBA - Final MRP (July 2013)]

In this example, the road sections part of the coverage area of the purple street cabinet are in purple and the road sections part of the coverage area of the red street cabinet are in red. This is to illustrate which road sections are connected to either the purple or red street cabinet.

Once the road sections and their corresponding street cabinet are identified, the "shortest path algorithm" is then implemented to get the following paths:

- The shortest path between each building and its corresponding street cabinet (depending on the road on which the building is located);
- The shortest path between each street cabinet and the node.

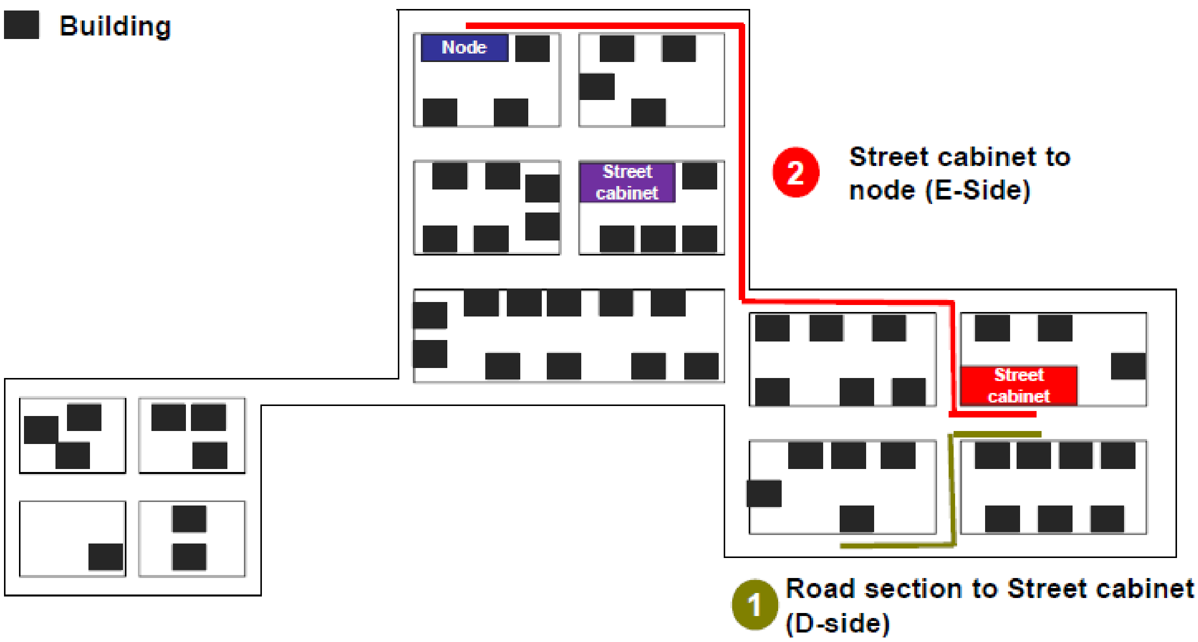

Illustration 5.7. Configuration of the shortest possible path for E-side and D-side [Source: DBA - Final MRP (July 2013)]

By means of this algorithm, for each network path (MDF to PDP for example), the road/street sections that are to be followed (identified for example by a number) are identified.

5.4.2.3. Access network dimensioning

Using the road network database and the shortest path algorithm, it is possible to determine exactly on each section which network elements should be rolled out in every part of the country:

- The shortest path algorithm defines the path of each cable:

Example: In the next illustration, the shortest path has been identified for several road sections.

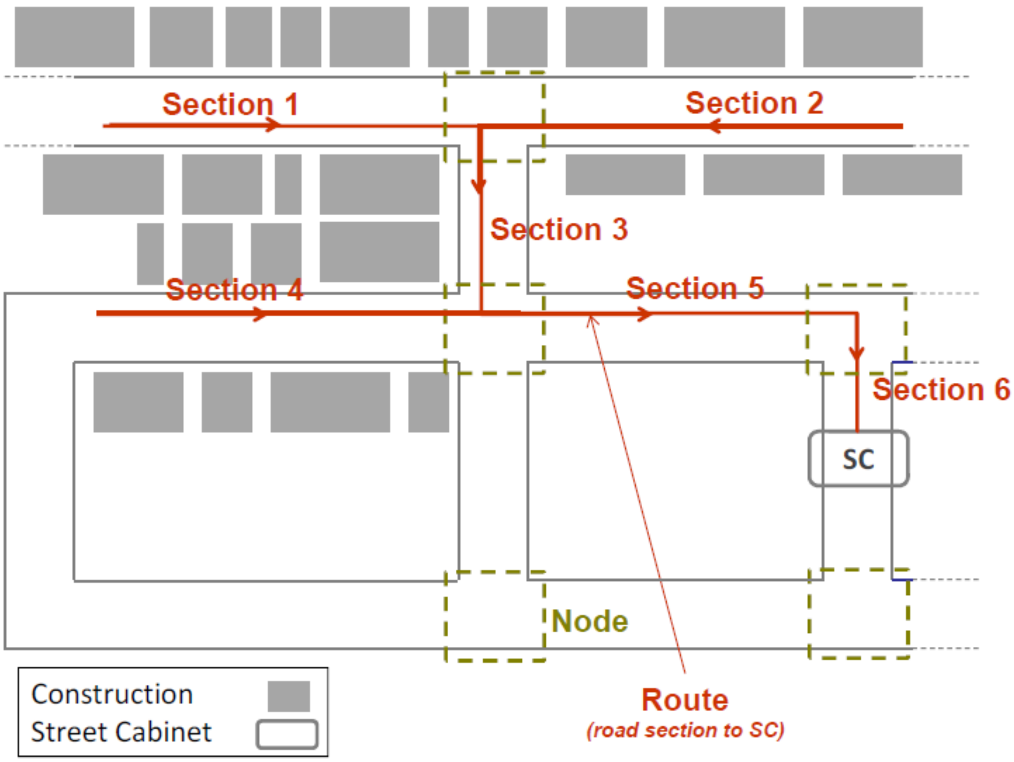

Illustration 5.8. Shortest path algorithm applied to a simple road network [Source: DBA - Final MRP (July 2013)]

- Knowing the path of each cable, it is possible to compute the demand on each section:

Example: Based on the road network shown in the previous illustration, the components, i.e. the road sections, of each route linking each section to the street cabinet can be identified. E.g. the route linking section 3 to the street cabinet is starting from section 3, then goes through section 5 and ends at section 6.

Route ID	First section	Second section	Third section	Fourth Section
Route1	Section 1	Section 3	Section 5	Section 6
Route2	Section 2	Section 3	Section 5	Section 6
Route3	Section 3	Section 5	Section 6	
Route4	Section 4	Section 5	Section 6	
Route5	Section 5	Section 6		

Illustration 5.9. Route identification applied to previous road network [Source: DBA - Final MRP (July 2013)]

Having identified the components of each road, it is easy to know for each section which route goes through it. E.g. only Route1, Route2 and Route3 all go through section 3. As a consequence the section 3 network elements should be dimensioned so that the demand carried by cables following Route1, Route3 and Route3 can be handled. The demand carried by cables following Route1 is the demand from the first section of this route, i.e. the demand of section 1. The demand carried by cables following Route2 and Route3 is likewise respectively the demand of section 2 and section 3. Therefore, the network elements located on section 3 should handle the demand of section 1, section 2 and section 3.

- Knowing the demand and using the network dimensioning rules (such as spare capacity), it is possible to assess exactly the number of copper pairs/fibres/cables needed on each section;
- Using the list of available cables, it is therefore possible to assess the number and the size of the cables that need to be rolled out on each section;
- The number of ducts and then the size of the trenches are directly derived from the number of cables rolled out. However, these do not depend only on the cables rolled out for the access network but depend also on the cables rolled out for the core network. Indeed the core cables are sometimes sharing the same trenches and potentially the same ducts as the cables rolled out for the access network. It is therefore necessary to dimension the infrastructure part of the core network at the section level.

The dimensioning of the core network infrastructure is detailed in section '5.4.3 Core and transmission networks'.

Other elements are also dimensioned at the section level:

- One piece of jointing equipment is installed for each cable at each crossroad (so at the beginning of each section as a section is the part of a road located between two crossroads). Indeed, a piece of jointing equipment is needed at each crossroad either to cross the road or to turn;
- One piece of jointing equipment is installed for each cable if the distance between two jointing equipment installed by the previous rules exceeds a threshold set according to operators' rules.
- Knowing the locations of the jointing equipment, it is then possible to compute the number of chambers required as a piece of jointing equipment should be installed in a chamber in case the network is underground (on a pole if the network is aerial).

Supporting criterion 34: The access and transmission networks should be dimensioned at section level.

5.4.3. Core and transmission networks

5.4.3.1. Dimensioning of the active core and transmission elements

Within an all-IP core network there is no need for SDH/PDH transport networks.

Specific equipment for data transport, rather than switching/routing, is therefore likely to be limited to the use of repeaters on long distance routes.

Microwave links should be avoided wherever practical due to the relatively limited data carrying capacity of such links compared to fibre optic cable.

Supporting criterion 35: Repeaters should only be used on long distance routes. Any use of microwave links within the core network will also need to be justified.

5.4.3.2. Dimensioning of the civil infrastructure for the core and transmission networks

Modelling infrastructure is a very important part of modelling the transmission network because the infrastructure is likely to be the most expensive part, accounting for up to 80 percent of the investment in an all-IP transmission network. It can also be a contentious exercise since the same assets are used to support a large number of different services, implying significant shared and common costs which will need to be allocated.

In this section, the infrastructure category is defined to include all trench, duct and fibre optic cables (and ancillary items such as manholes, fibre splicing trays etc.).

Supporting criterion 36: The LRAIC model should identify infrastructure costs associated with the transmission network. The model should identify separately the costs of cable, duct and trenches.

Core cables

Contrary to the access network, the core network includes often resilient routes. Furthermore, the path followed by the core cables may not be the shortest path between two core nodes and resilient cables are often following different paths. This is generally due to the specificities of each country and is therefore more difficult to model properly from a bottom-up perspective. Moreover, these paths may not follow the road network or may follow some roads that the access network is not following such as highways.

The first step of modelling the core infrastructure is therefore to collect a digitalised map of the core cables network from the operator. With this map, it is possible to count the number of core cables located in each section in Denmark or to determine the list of connections between core sites.

In accordance with section '5.4 Network dimensioning' the number of fibres per cable should be calculated using bottom-up demand for fibre (this is possible for fibre cables that goes out existing sites of the network), existing configurations and assessment of the impact of DWDM in the need for fibre in the modelled operator's network.

The length of each cable on each section should be determined on the basis of the shortest path algorithm. To apply this algorithm the list of physical connections between sites of the core network (including resilient connections) will be requested to the modelled operator.

Supporting criterion 37: The core cables network data (list of connections between core sites) should be collected from the modelled operator.

Core ducts

Knowing the number and size of core cables located in each section in Denmark, the number of ducts (and possibly micro-ducts or sub-ducts, depending on the engineering principles used) required per section is derived.

The length of each duct should be the length of the section.

Supporting criterion 38: The length and the cost of the core ducts should be derived from the core cables calculations.

Trenches

Trenches should be constructed wherever a core cable is rolled out (only one trench on one section even if multiple cables are rolled out).

The trenches are shared between the core network and the access network as explained in section '5.6 Allocation of costs to services'.

Supporting criterion 39: The LRAIC model should show the amount of duct and trench that is common to the core and the access network and any other utility. It should show also the amount of duct and trench specific to the core network and to the access network.

5.4.3.3. Dimensioning of the core platforms

Core platforms required to provide the modelled services will be included in the model. In order to perform the dimensioning of these platforms, the model will rely on the capacity of the typical platforms installed by the modelled operator and the demand requirements that these elements shall satisfy.

It should be noted that core network platforms which are not directly involved in the provision of wholesale services (e.g. TV platforms) will not be included in the cost model.

5.5. Costing the Network

Having dimensioned the network, i.e. having assessed for each section which and how many elements are needed, it is possible now to calculate the cost of the network. Calculating the cost of the network includes estimating the level of the capital expenditures and the operating expenditures separately for each type of network element:

- **Capital expenditures**: Based on the number of network elements of a given type required for each year, the model will assess the associated investment levels. These investments shall be annualised for each type of network element based on the methodologies determined in section '4.4 Depreciation Methodologies' This cost category will include both, depreciation and cost of capital charges.
- **Operational expenditures**: The total operational expenditures for each type of network element for a given year can be calculated by multiplying the unitary yearly OpEx by the number of network elements required for that given year.

Once these costs have been calculated for the whole network, these are ready to be allocated to services.

5.6. Allocation of costs to services

The final step in the process will be to calculate the costs for various services under scrutiny. Based on the hypothetical network that has been built, the model needs to calculate the LRAIC costs attributable to each of the various services.

This means that all of the different cost categories - direct network costs, indirect network costs, operating costs and overheads - will be aggregated into network elements that will form the "building blocks" when calculating the costs of the services.

The cost categories that fall under the heading direct network costs should be sufficiently disaggregated that each cost category has only one cost driver. For example, a DSLAM consists of both line cards and concentrating functionality, and therefore its costs depend on subscribers and traffic. Therefore, there should be at least two cost categories, the costs of line cards and the costs of concentrating functionality (this can theoretically be split into more than one cost category depending on the modularity of the equipment acquired), instead of a single cost category measuring the total cost of the equipment.

Supporting criterion 40: The LRAIC model should identify cost categories such that there is only one exogenous cost driver for each. The model should aggregate, in a clear manner, the cost of network elements used in the modelled services such that it is clear how the overall cost of a particular service is comprised of the cost of individual network elements.

The allocation of the network costs to services will be based on the methodologies described in section 4.1 Direct, common costs and Corporate Overheads.

However, for the sake of clarity, the paragraphs below describe the specific approach to be adopted with regards to two areas of special relevance for the model:

- Allocation of shared costs of civil infrastructure
- Allocation of costs to access services

5.6.1. Allocation of shared costs of civil infrastructure

As detailed in section '5.4 Network dimensioning', civil infrastructure is commonly shared between different networks (e.g. copper access, fibre access, transmission). It is therefore necessary to define a specific allocation methodology to disaggregate the costs of these elements between the different networks (and, therefore, between the services provided in each of them) that use them. Based on the information available at road section level for both ducts and trenches, including the identification of the presence or not of cables rolled out for each network, the costs of that road section will be allocated between the different networks involved.

In the case of the trenches, this allocation will be performed in three steps.

- **Step 1**. If the road section is shared with other non-fixed telecom networks (such as electricity, water or mobile telecom networks), then half of the cost (50%) of the said section will not be considered in the cost model. If the road section is used exclusively for fixed telecom networks, then 100% of the costs will be considered in the model.

In the case that this information is not available at road section level, more aggregated data (e.g. at postal code level) may be used.

- **Step 2**. If the road section is occupied by both core and at least one access network, half of the cost (50%) considered in the model from Step 1 will be allocated to the core network and half (50%) will be allocated to access networks. If the road section is occupied only by either access or core networks 100% of the cost considered in the model will be allocated to access or core networks.
- **Step 3**, If the road section is used by more than one access network (e.g. copper and fibre), the costs allocated to access networks in Step 2 will be evenly split between the access networks involved. If the road section is only used by one access network, all costs will be allocated to that access network.

As an example, a trench being used for electricity, core networks, copper and fibre access networks will allocate the costs in the following manner: 50% of the costs to electricity (not included in the cost model), 25% to core networks, 12.5% to copper access networks and 12.5% to fibre access networks.

In the case of ducts, preferably the costs will be allocated to the relevant networks based on the volume (cross-section multiplied by the length) of the cables within each duct. However, in the case that this information is not available, a similar approach to the one presented for trenches above may be followed.

The sharing of these infrastructure assets will be crosschecked with top-down data from the modelled operator.

Main criterion 17: The cost of shared assets (trenches and possibly ducts) will be allocated to the different networks (core, access and other non-fixed-telecom networks) based on their usage of this infrastructure.

5.6.2. Allocation of costs to access services

The model will calculate the costs of access services based on the costs that are line-dependant.

For that purpose, the sum of annualised capital expenditures and operating costs will be divided by the appropriate number of active lines.

The LRAIC model will have the ability to assess the costs at different geographical levels which will enable the comparison of the cost distribution over the country (see section '6.1 Geographical De-Averaging').

Supporting criterion 41: The LRAIC model should compute a cost per line for each geographical level by dividing the sum of the annualised capital expenditures and the operating costs by the appropriate number of present active lines in the network of the modelled operator.

5.7. Ancillary services

Ancillary services refer to ad-hoc services that support the provision of the main services defined in section '3.2 Services' such as VULA, bitstream or local loop unbundling. For instance, typically, the initiation of the provision of a new bitstream service requires a one-off activation/installation service or activity as well as a co-location to interconnect the equipment of the access seekers.

Given that these ancillary services are an intrinsic part of any reference offer, the fixed LRAIC model should be capable of determining their costs. However, differently from the main services defined in section '3.2 Services', a bottom-up calculation is not the most appropriate approach to determine the costs of the ancillary services, as these are mostly based on one-time actions (e.g. activations), or recurrent processes which should be analysed from a top-down perspective (e.g. space occupied for co-location).

Therefore, a specific calculation module will be included in the fixed LRAIC model, which will not be directly connected to the cost calculations performed for the services defined in section '3.2 Services' to determine the costs of the ancillary services. The main inputs for the calculation of the costs of the ancillary services will be:

- The time (measured in man-hours) required from internal and external employees to carry out the one-time actions.
- The man-hour cost of the internal and external employees involved in the execution of the one-time actions.
- The cost of other necessary resources (e.g. materials, systems, etc.) involved in the provision of the service.

The model should be able to calculate all the relevant ancillary services based on the up-to-date market decision determined by DBA.

6. Model outputs

6.1. Geographical De-Averaging

Costs are likely to differ significantly between areas in the access network; variations are likely to be smaller, in relative terms, for the core network. In addition, it is quite difficult to measure costs by area in the core network since, for example, transmission links may pass through more than one type of area.

Focusing on the access example, there are at least three reasons for differences in costs by area:

- trenching/ducting costs are likely to be higher in urban than rural areas;
- distances between the exchange and the customer tend to be shorter in urban than in rural areas; and
- cables tend to carry more pairs in urban than rural areas.

The first factor would result in higher access costs in urban areas; the latter two factors in lower costs. In overall terms the last two factors are likely to dominate, implying lower access costs in urban areas. The difference could be significant.

In this regard the model shall be aligned with the regulatory needs of DBA. Particularly, in the latest analysis of markets 3a and 3b, DBA lifted the price regulation obligations applicable to TDC for fibre-related services in some specific areas of Denmark, introducing a geographical disaggregation of the regulatory obligations imposed.

Therefore, the model shall be able to calculate the costs stemming from regulated areas only. While so far, the distinction between regulated and deregulated is performed at postal code level, the model should be able to accommodate other levels of disaggregation (e.g. central office or even household level).

The default level of disaggregation of the results should include:

- Disaggregation per geotype (e.g. urban, suburban and rural). This disaggregation will be at DSLAM/OLT/CMTS level in order to ensure all access elements belong to a single geotype. The disaggregation of the country per geotype will be based on the density of buildings.
- Disaggregation between regulated and non-regulated areas.

- Disaggregation at regional level. This disaggregation will be based on the five regions in Denmark (Hovedstaden, Midtjylland, Nordjylland, Sjælland and Syddanmark) to ensure transmission costs are adequately represented.
- Disaggregation between single-dwelling and multi-dwelling buildings.

Main criterion 18: The model will provide results at different levels of disaggregation (geotype, regulated/deregulated areas, regions, single/multi dwelling units) as well as nationwide. The model will also provide room to calculate costs at a higher level of detail (e.g. central office or even household level) on an ad-hoc basis.

6.2. Level of Detail

The model should also seek to identify operating and asset costs separately. Only those operating costs necessary to bring an asset into working for its intended use, such as transport, installation and commissioning should be capitalised.

Supporting criterion 42: Costs related to assets can include capitalised operating costs ("own work capitalised").

The results of the LRAIC model are service costs. In order to facilitate the understanding and review of the LRAIC model, it is relevant to show not only service costs but also costs of the service components. For example, rather than showing only the cost of a VULA/BSA wholesale line, it could be very relevant to show also the cost components of this service, such as the cost of the civil infrastructure, the cost of fibre, the cost of the splitters, etc.

Supporting criterion 43: The LRAIC model should have the ability to show not only the cost of the services but also the cost of the components involved in the provision of these services.

6.3. Charging basis

Several charging bases can be used to cost a given service. These charging bases include (but are not limited to):

- DKK per kbps (capacity-based charging);
- DKK per line per month

For each service, the charging basis must be selected in order to provide the different stakeholders with the appropriate incentives. It is also preferable for the charging basis to be consistent with the cost drivers of the service. For instance, if BSA was priced on a 'per minute' basis, it would not be in line with cost drivers (capacity). In addition, the charging basis has to be compliant with the applicable legal and regulatory provisions.

Supporting criterion 44: The charging basis should be as consistent as possible with the cost drivers of the service.

7. LRAIC model validation and update process

7.1. Top-down validation

The LRAIC model is based on a bottom-up approach. However, a top-down validation can still be conducted in order to increase the robustness of the final costing results.

The outputs of the bottom-up model should be compared with modelled operator data. This is a two-stage process:

- **calibrate the model assets** in order to have output volumes that are broadly in line with those of the modelled operator(s) (e.g. trench kilometres, cables kilometres);
- **broadly compare the model expenditures** (separately for CAPEX and OPEX).

Where considered reasonably efficient, the model's total CAPEX and OPEX should reflect those of the modelled operator. This reconciliation should be performed with the highest level of granularity possible, making sure that the cost items compared in the bottom-up and the accounts have a comparable scope.

As a consequence, the data request will include some top-down information enabling to perform the top-down validation.

Supporting criterion 45: Information to aid a top-down validation will be requested from the modelled operator(s). The validation will include both a calibration of assets and a reconciliation of the cost base. For the avoidance of doubt, information to aid a top-down validation is limited to top-down asset information and cost data, which is distinct from a top-down cost model based on operator accounts.

7.2. Update process

LRAIC models are forward-looking models which include some forecasts: forecasts on the number of users, on the traffic, on the unit costs, etc. In order to inform DBA on the evolution of service costs in the future and in particular in order to verify the extent to which regulated prices evolve in line with underlying costs, a regular update of the LRAIC model is necessary. DBA intends to carry out annual updates.

Such updates can be a lengthy process and require significant time for both DBA but mainly the modelled operator. In order to facilitate the update of the LRAIC model, it is proposed to create a template spreadsheet listing key inputs of the LRAIC model which need regular updates. This template spreadsheet should be easily linked to a file system so that including the new inputs into the LRAIC model is not a lengthy process. This will also enable the modelled operator to collect updated data in a more automated way.

The LRAIC development process should therefore include the building of a template spreadsheet enabling easier and more automated updates of the LRAIC model.

Supporting criterion 46: The LRAIC development process should include the building of a template spreadsheet enabling easier and more automated updates of the LRAIC model.

8. Appendix

8.1. List of criteria

The criteria for the LRAIC model set out by DBA are listed below, differentiating between main and supporting criteria.

- **Main criteria**

Main criterion 1: A Current Cost valuation should be adopted to set the unit costs of the assets in the Bottom-Up cost model. Nevertheless, the GRC originated from fully depreciated assets should be excluded for the categories listed in the column "Valuation should exclude fully depreciated assets" of Illustration 2.1.

Main criterion 2: The LRAIC model should be based on forward-looking long run average incremental costs. No migration costs should be included. The LRAIC model should allow coverage of common costs. These costs should be shown separately.

Main criterion 3: The model will calculate the service provisioning costs from 2005 to 2038, or as otherwise concluded, based on the data provided by additional years may be included based on the availability of information. The modelling timeframe will at least cover the 2018 – 2028 period. Additionally, it will incorporate a time-frame up to, at least, 2070 to properly implement the economic depreciation algorithms.

Main criterion 4: A single model will be built, with a single increment comprising all access and traffic services. Costs of ancillary services (such as co-location, activation and interconnection points) will be calculated stand-alone as they are not directly related to the main network topology or architecture as such.

Main criterion 6: The model should include all relevant access, broadband leased line, TV and ancillary services.

Main criterion 7: The model will not include voice services. Including voice services in the model would complicate the model with a negligible impact on the cost calculation of regulated services. Consistently, voice-specific core platforms (e.g. MGW) will not be modelled either. The model will, however, allocate the relevant share of common costs to voice services based on an ad-hoc analysis from the existing LRAIC model.

Main criterion 8: The LRAIC model should assume that each access network technology supports its actual demand.

Main criterion 9: Capacity-based allocation for joint and common network costs should be implemented in the LRAIC model.

Main criterion 10: Corporate overheads costs should be allocated on the basis of the EPMU approach.

Main criterion 11: Prices used in the model should reflect those that an efficient operator would face, taking into account the scale of the modelled operator.

Main criterion 12: Operating costs for each network element should be calculated using a bottom-up assessment based on a percentage of capital cost, unless the operators can provide accurate estimations on the absolute yearly operational costs of each network element.

Main criterion 13: Tilted annuities and full economic depreciation should be implemented in the LRAIC model.

Main criterion 14: WACC values considered in the cost model should be aligned with the up to date decisions determined by DBA.

Main criterion 15: The LRAIC model should use as much as possible locations (X;Y geographic coordinates) of each network node of the operators.

Main criterion 16: The model should use the coverage areas of the modelled operator.

Main criterion 17: The cost of shared assets (trenches and possibly ducts) will be allocated to the different networks (core, access and other non-fixed-telecom networks) based on their usage of this infrastructure.

Main criterion 18: The model will provide results at different levels of disaggregation (geotype, regulated/deregulated areas, regions, single/multi dwelling units) as well as nationwide. The model will also provide room to calculate costs at a higher level of detail (e.g. central office or even household level) on an ad-hoc basis.

- **Supporting criterion**

Supporting criterion 1: The model will take the public funding that operators have received from the Danish Energy Agency (Energistyrelsen) in the deployment of broadband networks into account. The applicable public funding will be deducted from the cost base considered in the cost model, to ensure that it reflects the actual costs incurred by the modelled operator.

Supporting criterion 2: For the cable-TV network, the model should

Supporting criterion 3: The model should consider line cards as part of the access network. The DSLAM located at the cabinet (in the case of FTTC deployment) should be considered as part of the core network. The cost of trenches should be allocated between the core and access networks in consistency with the realities observed in the actual networks.

Supporting criterion 4: When dimensioning the network, the leased-lines traffic volume should include leased lines provided to retail customers, to other operators and to the network operator. Leased lines used by the network operator should not be double counted. The model should not calculate the costs of leased lines explicitly. Leased lines should only be included for dimensioning of the network and for ensuring that a fair amount of costs is allocated to leased line services as well.

Supporting criterion 5: For PTP, both an unbundling product at the ODF and a BSA product will be modelled. For PON, both an unbundling product at the splitter and a BSA product will be modelled.

Supporting criterion 6: Bitstream services in coaxial networks should be aligned with the current wholesale commercial offers in the market.

Supporting criterion 7: The model should show, for each service, routing factors or, if not possible, a consistent alternative measure of how, on average, each service uses the core network and the access network. The model should also be flexible enough to allow for changes in routing factors / alternative measures.

Supporting criterion 8: The model should only include IP packet switch technology.

Supporting criterion 9: The model should not include SDH.

Supporting criterion 10: The model should not include DWDM equipment in the core network, except for long distances.

Supporting criterion 11: The model should include both PTP and PON network architectures for FTTH networks, reflecting the actual modelled operator.

Supporting criterion 12: The choice of technology and degree of optimisation is subject to the scorched-node assumption and the requirement that the modelled network as a minimum should be capable of providing comparable quality of service as currently available on the modelled operator's network, and be able to provide functionality comparable to that of the existing services.

Supporting criterion 13: The cost of passing all the premises within an area should be modelled. Drop wires should be deployed (or decommissioned) in the model based on the strategies followed by SMP operator(s), as long as these are considered to be representative of an efficient operator.

Supporting criterion 14: The LRAIC model will present the total direct network costs of the different network elements separately for CAPEX and OPEX.

Supporting criterion 15: The LRAIC model should consider indirect costs, such as accommodation, costs of installation, support systems, power, and cooling.

Supporting criterion 16: The LRAIC model should have the possibility of including a risk premium for NGA/VHCN networks.

Supporting criterion 17: The LRAIC model should include the functionality to consider working capital. However, unless the modelled operator quantitatively proves its existence, it will be left empty (i.e. no working capital will be considered).

Supporting criterion 18: The starting point when building the bottom-up model is the level of demand in Denmark for all the modelled services.

Supporting criterion 19: The LRAIC model will include demand forecasts until 2038 (or earlier if otherwise concluded based on data availability) for the modelled services.

Supporting criterion 20: The LRAIC model should have the capability to be able to show the demand for each major broadband service speed in terms of the number of customers.

Supporting criterion 21: Demand for TV services such as Multicast-IPTV and Video On Demand should be included in the model.

Supporting criterion 22: The LRAIC model should show the demand of number of leased lines by volume and bandwidth. Information should be sought on how the amount of leased line capacity sold varies across the different regions of the country and by hierarchical level within the network.

Supporting criterion 23: The usage factors used for the determination of the demand drivers in the model need to be consistent with the underlying network architecture.

Supporting criterion 24: The LRAIC model should clearly identify busy-hour information for all relevant traffic. The LRAIC model should also be flexible enough to allow for changes in these figures. Information on the busy hour will need to be sourced from the operators for all relevant services.

Supporting criterion 25: The LRAIC model should demonstrate that the modelled network provides services at an appropriate level of quality for an efficient modelled operator, particularly for real time traffic (such as IPTV) and non-contended ("leased lines") traffic.

Supporting criterion 26: The LRAIC model should show the costs of a network with an efficient configuration operated by an efficient company, based on the latest proven technological solutions and an optimally structured organisation. However, the starting point should be the existing geographic network architecture in the modelled operator's network. This implies that equipment should be placed at the existing geographical locations of the modelled operator's network nodes (the scorched node assumption).

Supporting criterion 27: The hierarchy of the exchanges adopted in the LRAIC model should be kept unchanged. The use of DSL cards instead of POTS cards should be modelled.

Supporting criterion 28: The hierarchical design adopted in the LRAIC model considers the following factors: cost, the impact on other parts of the network, security, technical feasibility, and consistency with the evolution of the telecoms networks.

Supporting criterion 29: The LRAIC cost model will be based on a database software and Microsoft Excel. The usage of database solutions will be limited to the geographical assessment of the access network to facilitate the review and understanding of the LRAIC model by stakeholders.

Supporting criterion 30: The LRAIC model should use the road network database provided by the DAR.

Supporting criterion 31: The LRAIC model should use the data on buildings provided by DAR or equivalent sources if not available.

Supporting criterion 32: The LRAIC model should use the operators' networks hierarchies. However, as regards fibre access network, PTP should be modelled with the same hierarchy as other access networks.

Supporting criterion 33: The LRAIC model should use the "shortest path algorithm" to connect two nodes together by following the real Danish road and street network.

Supporting criterion 34: The access and transmission networks should be dimensioned at section level.

Supporting criterion 35: Repeaters should only be used on long distance routes. Any use of microwave links within the core network will also need to be justified.

Supporting criterion 36: The LRAIC model should identify infrastructure costs associated with the transmission network. The model should identify separately the costs of cable, duct and trenches.

Supporting criterion 37: The core cables network data (list of connections between core sites) should be collected from the modelled operator.

Supporting criterion 38: The length and the cost of the core ducts should be derived from the core cables calculations.

Supporting criterion 39: The LRAIC model should show the amount of duct and trench that is common to the core and the access network and any other utility. It should show also the amount of duct and trench specific to the core network and to the access network.

Supporting criterion 40: The LRAIC model should identify cost categories such that there is only one exogenous cost driver for each. The model should aggregate, in a clear manner, the cost of network elements used in the modelled services such that it is clear how the overall cost of a particular service is comprised of the cost of individual network elements.

Supporting criterion 41: The LRAIC model should compute a cost per line for each geographical level by dividing the sum of the annualised capital expenditures and the operating costs by the appropriate number of present active lines in the network of the modelled operator.

Supporting criterion 42: Costs related to assets can include capitalised operating costs ("own work capitalised").

Supporting criterion 43: The LRAIC model should have the ability to show not only the cost of the services but also the cost of the components involved in the **provision** of these services.

Supporting criterion 44: The charging basis should be as consistent as possible with the cost drivers of the service.

Supporting criterion 45: Information to aid a top-down validation will be requested from the modelled operator(s). The validation will include both a calibration of assets and a reconciliation of the cost base. For the avoidance of doubt, information to aid a top-down validation is limited to top-down asset information and cost data, which is distinct from a top-down cost model based on operator accounts.

Supporting criterion 46: The LRAIC development process should include the building of a template spreadsheet enabling easier and more automated updates of the LRAIC model.

8.2. List of acronyms

BSA	Bitstream Access
BU	Bottom-Up
BU-LRAIC	Bottom-up Long-run Average Incremental Costs
CAPEX	Capital expenditure
CMTS	Cable Model Termination System
CPE	Customer Premises Equipment
DBA	Danish Business Authority
DKK	Danish Krone
DN	Distribution Node
DP	Distribution Point
DSLAM	Digital Subscriber Line Access Multiplexer
DWDM	Dense wavelength division multiplexing
EC	European Commission
EPMU	Equal Proportionate Mark-Up
FDP	Final Distribution Point
FTTC	Fibre To The Cabinet
FTTH	Fibre To The Home
GPON	Gigabyte Passive Optical Networks
GPS	Global Positioning System
IMS	IP Multimedia Subsystem
IN	Island Node
IP	Internet Protocol
ITU	International Telecommunication Union
Kbps	Kilobit per second

LA	Last Amplifier
LRAIC	Long-run average incremental cost
LRIC	Long-run incremental costs
Mbps	Megabit per second
MDF	Main Distribution Frame
MEA	Modern Equivalent Asset
MPEG	Moving Picture Expert Group
MRP	Model Reference Paper
MSAN	Multi-Service Access Nodes
NGA	Next Generation Access
NGN	Next Generation Network
NRAs	National Regulatory Authorities
ODB	Optical Distribution Box
ODF	Optical Distribution Frame
OLT	Optical Line Terminal
OPEX	Operational expenditure
PAP	Primary Access Point
PCP	Primary cross connect Point
PDH	Plesiochronous Digital Heriarchy
PDP	Primary Distribution Point
PON	Passive Optical Network
POTS	Plain Old Telephone Service
PSTN	Public Switched Telephone Network
PTP	Point to Point
SDH	Synchronous Digital Hierarchy
SDP	Secondary Distribution Point
SMP	Significant Market Power
TD-LRAIC	Top-down Long-run Average Incremental Costs
TDM	Time Division Multiplexing
VoD	Video On Demand
VoIP	Voice over IP
WACC	Weighted Average Cost of Capital
xDSL	Digital Subscriber Line