Modification and development of the LRAIC model for fixed networks 2012-2014 in Denmark

Draft Model Reference Paper

Danish Business Authority

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Summary

0 Introduction

0.1 Context

The Model Reference Paper (MRP) outlines the features and key principles applying to the development of the long-run average incremental cost (LRAIC) model for fixed networks used to determine LRAIC based cost for certain (wholesale) access and interconnection services in Denmark. LRAIC based costs can be useful inputs for the Danish Business Authority (DBA) to set cost based prices. Since 2003, LRAIC models have been used by the DBA to set prices for a number of services that includes interconnection, bitstream, local loop unbundling, backhaul, collocation and ancillary services.

The regulatory basis for using the LRAIC method is set out in the Act on Competitive Conditions and Consumer Interests in the Telecommunications Market.

Over the last ten years, several extensive changes have affected the cost structure and the cost levels of fixed network operators in Denmark. As a consequence, the DBA has updated its LRAIC model on a regular basis[1] to make sure that regulated prices are set accordingly. A number of structural upgrades to the model have been undertaken since 2003 to take into account major market and technological changes. Updates have been implemented following discussions with all relevant market players as well as extensive consultation processes in order to properly model a network with an ideal configuration operated by an ideal company, based on the newest technological solutions and an optimally structured organisation.

The DBA has commissioned TERA Consultants to modify and develop the LRAIC model for fixed networks in Denmark for the period 2012-2014 in order to set prices from January 2015. This project is built along 4 main phases[2]: 1) preparation of a Model Reference Paper (MRP), 2) Revision and development of a LRAIC model, 3) Model circulation and 4) Setting of maximum prices.

As part of the first phase of this project, this document is the draft MRP. The DBA is seeking comments from stakeholders on this draft MRP through a public consultation. When writing the final MRP, relevant comments raised by stakeholders will be taken into account.

The MRP will be used in the second phase of the project as a reference or guidelines to build the LRAIC model. Criterions which shall be used when modifying and developing the LRAIC model are listed at the end of main sections and also at the end of the document (in boxed text).

[1] The DBA has also updated the inputs of the model on a yearly basis: demand forecasts for the individual services, wages for technicians and cost of capital.

[2] Excluding kick off of the project which occurred in December 2012 and January 2013.

While preparing this draft MRP, some comments already stated by stakeholders during the kick-off meeting or during the MEA consultation have been taken into account such as:

- The new LRAIC model should be less complex than the previous LRAIC models;
- The new LRAIC model should be able to calculate access network at more granular level;
- The new LRAIC model should be able to show details of the cost elements included in the LRAIC cost of services.

It should be noted that some sections of this document are identical to sections of the previous MRP[3]. Since some sections and criteria of previous MRP are still valid for the new LRAIC model, it has been decided to keep corresponding sections unchanged to facilitate the review of the document by stakeholders. Footnotes are used to specify which sections of this draft MRP are the same as previous MRP.

0.2 Conclusions from the MEA assessment

As a part of the project, the DBA has conducted a modern equivalent asset (MEA) assessment aiming at answering the following two questions:

- What is the MEA for copper and cable-TV?
- Is VoIP a MEA for PSTN?

Following the public consultation process on the MEA assessment [4], it was decided that:

- FTTH is the MEA for copper and cable TV access networks;
- VoIP technology is the modern equivalent technology for PSTN.

In addition to these decisions, the DBA determined that the following elements shall be modelled:

- For the passive part of the access network, the DBA **shall develop a LRAIC model for the copper technology and the FTTH technology**. It is important to underline that the copper technology includes both a full copper topologies but also a FTTC. Even if FTTH is considered as the MEA for copper, the DBA considers that the computation of copper-based regulated product prices could require the identification of cost differences between copper and FTTH[5].

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[3] See Model Reference Paper Final version, The National IT and Telecom Agency, 18. September 2008 and Report for National IT and Telecom Agency 2010/11 upgrades to the NITA LRAIC model, Final model reference paper, 03 September 2010.

[4] DBA, Modification and development of the LRAIC model for fixed networks 2012-2014 in Denmark MEA ASSESSMENT, February 2013.

http://www.erhvervsstyrelsen.dk/file/348279/udkasttilanalyse.pdf

[5] In addition, it is our understanding that TDC does not intend to deploy a large scale FTTH network in the medium term.

- **The costs of a coax network will be assessed** but will be based on the FTTH cost model since the passive part of the cable TV access network is already significantly based on fibre. In the cable TV network, fibre will be deployed closer to the end-users in the coming years and this should make the passive parts of cable TV and FTTH networks very similar.
- However, **the specific assets in the active part of the networks** (e.g. OLT for fibre, DSLAM for copper at the MDF or at the street cabinet for FTTC, MPEG stations and amplifiers for cable TV) will be modelled to identify cost differences between technologies. These assets have a shorter lifetime and are very different from one technology to another.
- For voice, **the DBA will model VoIP technology with voice simulation over NGN** using both TDM and IP-based interconnection. PSTN simulated over NGN appears to be the MEA for PSTN today.

The current draft MRP subsequently takes into account the conclusions above as a starting point for the development of the LRAIC model.

0.3 Structure of this paper

This paper specifies the criteria and minimum requirements for the bottom-up model and the cost analyses. The paper has the following structure:

- **Section 1** presents the costing methodology with a focus on the LRAIC approach;
- **Section 2** describes the networks, services, routing factors and technologies to be modelled and the evolution of the demand
- **Section 3** presents the different types of costs and how they are allocated to services;
- **Section 4** describes the model implementation; and
- **Section 5** describes how the outputs of the model will be presented;
- **Section 6** discusses the process of the LRAIC model update and the validation process.

1 Costing methodology

1.1 Cost orientation methodologies available to DBA

1.1.1 Legal context

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

According to the Price Control Order[6], the 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**"*

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

- Wholesale market for fixed network origination (market 2);
- Wholesale market for fixed-network termination (market 3)[7];
- Wholesale market for physical network infrastructure access (market 4);
- Wholesale market for broadband access (market 5).

As a consequence, **when choosing among cost orientation methods**, **DBA can choose between two cost standards: LRAIC and historic costs** (retail minus and reasonable price obligations are not cost orientation obligations).

The aim of this document is to introduce the principles of the cost approach which is to be followed for the implementation of a fixed LRAIC model in Denmark. However, as both LRAIC and historic costs can be considered when it comes to pricing, a brief overview of both approaches will be introduced and discussed hereafter.

The LRAIC method is introduced in §1.1.2 and historic costs are presented in §1.1.3.

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

[7] Several other operators are LRAIC-based regulated for market 3.

1.1.2 LRAIC costs and 'build or buy' signals

1.1.2.1 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*"[8].

As explained in the latest version of the MRP, 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)."*[9]

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**."*[10]

As LRAIC costs are based on the MEA, they will be representative of the costs that a new efficient operator investing today in fixed electronic communications networks would face.

1.1.2.2 The bottom-up approach

The LRAIC approach can be modelled as either top-down (TD-LRAIC[11]) or bottom-up (BU-LRAIC[12]).

[8] DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008.

[9] DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

[10] DBA, Executive Order on Price Control Methods, Section 3, dated 27 April 2011.

[11] 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.

[12] With bottom-up (BU) modeling, demand data is used as a starting point and an efficient network capable of serving that demand is determined by using economic and engineering principles.

Both approaches were previously implemented in Denmark (the LRAIC model was then called a "hybrid model")[13]. Under the hybrid approach, results of bottom-up and top-down approaches were compared and the bottom-up model was amended in order to reflect the actual cost base of an operator in Denmark taking into account efficiency adjustments.

Latest upgrades of the model include the bottom-up modelling of cable TV and FTTH networks without corresponding top-down models. The bottom-up models were reconciled with data from TDC.

The LRAIC model implemented in this project follows the bottom-up approach. 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 today (with current asset prices) 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 TDC.

The European Commission has recognised the benefits of bottom-up cost models:

> *"BU models use demand data as a starting point and determine an efficient network capable of serving that demand by using economic, engineering and accounting principles. BU models give more flexibility regarding network efficiency considerations and reduce the dependence on the regulated operator for data. A* ***BU model is synonymous with the theoretical concept of developing the network of an efficient operator*** *because it reflects the equipment quantity needed rather than actually provided and the model* ***ignores legacy costs****. (…) Although BU models are generally developed by NRAs, operators can contribute to the model inputs and assumptions. This will increase the transparency and objectivity of BU models, although it carries the risk that 'negotiated' figures, as opposed to more accurate figures, will be used in the model."* [14] (highlighted by the author).

1.1.2.3 'Build or buy' signals

From a regulatory point of view, the LRAIC method based on the MEA concept and implemented using the bottom-up approach can:

- give a good understanding of regulated operator's cost structure (it is a transparent approach) and enables one to determine more accurately the

[13] DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

[14] Commission staff working document accompanying the Commission Recommendation on the regulatory treatment of fixed and mobile termination rates in the EU, Explanatory Note, C(2009) 3359 final, SEC(2009) 599, May 2009, page 13.

changes in cost over time under uncertainty or where cost structures are expected to change;

- enable one to deal with efficiencies since costs are derived from service demand through established engineering rules;
- enable one to model the costs of services that have not yet been introduced or that have just been introduced;
- enable the DBA **to send appropriate "build or buy" signals**. If regulated prices to access the assets are set based on the MEA concept, it is equivalent for an alternative operator to buy access or to invest in an equivalent asset.

One of the potential drawbacks of this concept is that it is not necessarily linked to the costs actually incurred by the regulated operator. For example, LRAIC models may apply a positive value to assets that are fully depreciated in operator accounts. Also, in areas where alternative operators are unlikely to deploy alternative infrastructure, the MEA and LRAIC concepts may be less relevant for price setting. However, where NGA is deployed, it is representative of the costs an efficient player would face.

1.1.3 Historic costs

Historic costs method consists in taking the costs of the network as equal to the operator's accounting costs. It is a top-down method. Despite the drawbacks of top-down methods, the use of historic costs in regulation can be relevant in the case of "bottleneck" infrastructure. Bottlenecks in the market represent a situation where new entrants cannot realistically replicate the network of an incumbent (no infrastructure-based competition likely to develop). For example, there might be areas where it is impractical for alternative operators to build another network of trenches next to the incumbent's existing network.

Accordingly, alternative operators can only buy access to the incumbent's network to compete in downstream markets, and it is therefore less relevant to wish to send a "build or buy" signal. In other words, the costs that were actually incurred[15] to the owner of the bottleneck are more relevant than those that would be faced by a new entrant.

In its 2010 NGA recommendation, the European Commission considers that the historical costs effectively borne by the operators **should be considered for the pricing of the civil engineering** (e.g. ducts)[16]. Also, in the context of regulated access to Next Generation Access Network, the European Commission has confirmed these

[15] Including the extent to which those access assets have already been recovered by way of depreciation to avoid over or under cost recovery.

[16] *"Access to existing civil engineering infrastructure of the SMP operator on Market 4 should be mandated at cost-oriented prices. NRAs should regulate access prices to civil engineering infrastructure consistently with the methodology used for pricing access to the unbundled local copper loop. **NRAs should ensure that access prices reflect the costs effectively borne by the SMP operator.** NRAs should in particular take into account actual lifetimes of the relevant infrastructure and possible deployment economies of the SMP operator. Access prices should capture the proper value of the infrastructure concerned, including its depreciation."* European commission, NGA Recommendation, 20 September 2010. (highlighted by the author).

principles and specified that **costs derived from the accounts can be relevant for reusable legacy civil engineering assets**[17]**.**

As a consequence, in some instances, the use of historic cost information can be useful. Even if this draft MRP focuses on the LRAIC method, it is necessary to state that the new LRAIC model should include the ability to use historic cost information for some assets.

Criterion BU 1: The LRAIC model should include the ability to use historic cost information for some assets.

1.2 Focus on LRAIC[18]

1.2.1 LRAIC

As defined by the 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*"[19].

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 §1.2.2).

The definition of forward-looking costs depends on the time frame considered and on the computational assumptions that lie behind the optimisation function within the applied LRAIC method.

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[17] *"NRAs should adopt a BU LRIC+ costing methodology that estimates the current cost that a hypothetically efficient operator would incur to build a modern efficient network, which is in principle an NGA network…*

NRAs should value all assets constituting the Regulatory Asset Base (RAB) of the modelled network on the basis of full replacement costs, except for reusable legacy civil engineering assets.

NRAs should value reusable legacy civil engineering assets and their corresponding RAB on the basis of the indexation method. Specifically NRAs should set such RAB at the book value net of the accumulated depreciation at the time of calculation, indexed by an appropriate price index, such as the retail price index (RPI). NRAs should examine the accounts of the SMP operator where available in order to determine whether they are sufficiently reliable as a basis to reconstruct such book value. They should otherwise conduct a valuation on the basis of a benchmark of best practices in the EU." Commission Draft Recommendation on consistent non-discrimination obligations and costing methodologies to promote competition and enhance the broadband investment environment, December 2012.

[18] Adapted from former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

[19] DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008.

1.2.2 Defining the Increment

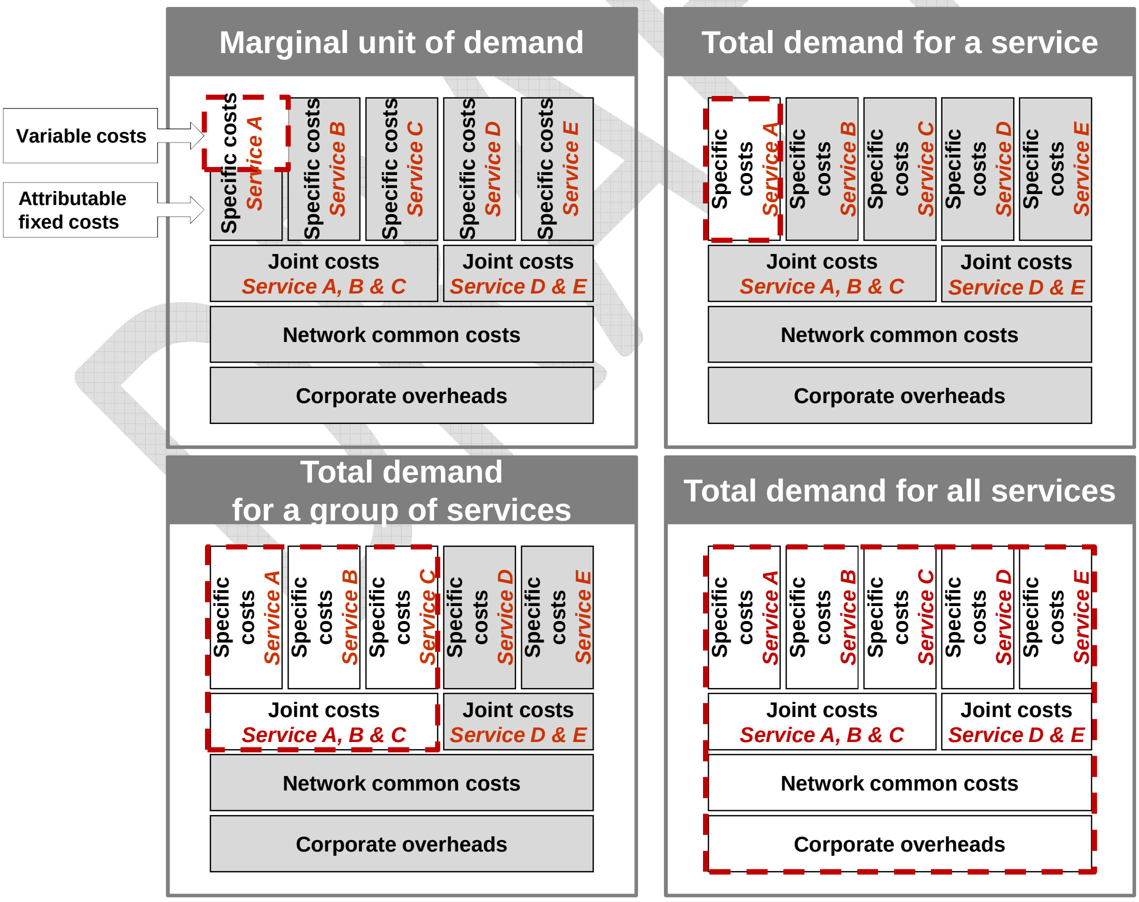
Incremental costs are the costs of providing either an increment or decrement of output when other increments of demand are unchanged.

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

Figure 1: Illustration of possible increment definitions



Source: TERA Consultants

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

For example (see Figure 1):

- 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 extend 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 extend from economies of scale. In these cases, all services bear a share of joint and common costs.

1.2.3 Implications of LRAIC[20]

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 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 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 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 were 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.

Criterion BU 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.

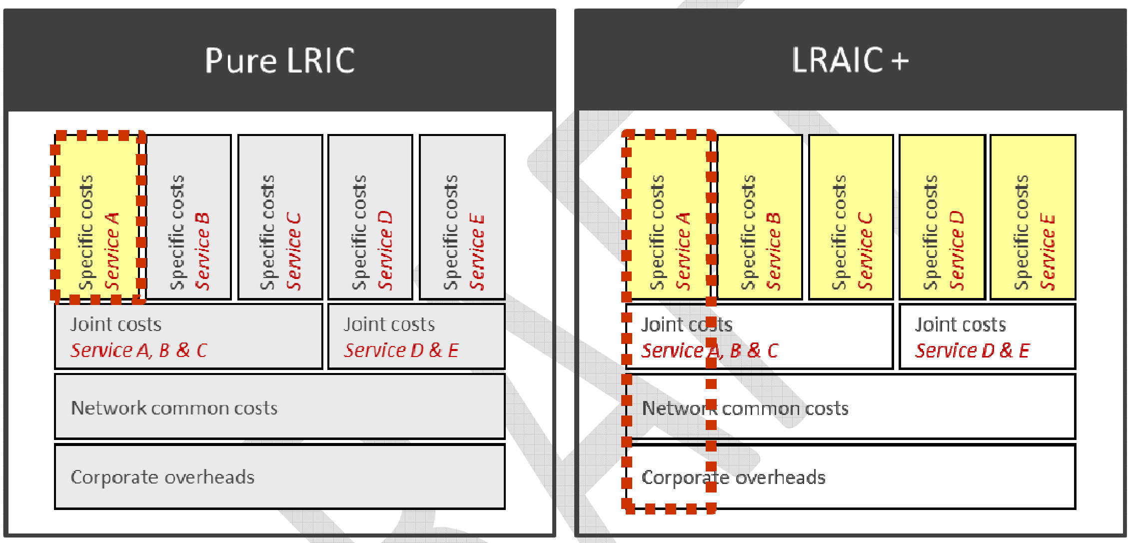
[20] See DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008.

1.2.4 Pure LRIC[21]

The pure LRIC approach considers a narrow increment: the traffic created by a single service (e.g. voice call termination). As a result, the associated incremental cost is the cost avoided in the scenario when the service is not produced. This cost is the difference between the total cost of producing all services and the total cost of producing all services minus the service considered.

Under this approach, the service considered benefits to a great extent from economies of scale. Neither network joint and common costs nor corporate overheads are taken into account (they are not incremental to the service increment considered).

Figure 2: Illustration of the pure LRIC and LRAIC + cost methodologies for service A



Source: TERA Consultants

The pure LRIC increment is applicable to the calculation of the termination service (i.e. Market 3), as implied in the EC 2009 Termination Rates Recommendation[22]:

> "*Within the LRIC model, the relevant increment should be defined as the wholesale voice call termination service provided to third parties. This implies that in evaluating the incremental costs NRAs should establish the difference between the total long-run cost of an operator providing its full range of services and the total long-run costs of this operator in the absence of the wholesale call termination service being provided to third parties. A distinction needs to be made between traffic-related costs and non-traffic-related costs, whereby the latter costs should be disregarded for the purpose of calculating wholesale termination rates…*"

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[21] Similar section as previous MRP.

[22] Commission Recommendation of 7.5.2009 on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU.

The EC Recommendation excludes non-traffic-related costs (these costs would correspond to (fixed costs attributable to the increment).

In other words, if all services were priced based on a pure LRIC approach, network common costs and corporate overheads would not be recovered. As a consequence, these common costs have to be allocated to other services than those being priced with a pure LRIC approach. This means that costs calculated for these other services can be above LRAIC costs. As a consequence, such an approach can only be used for services that do not represent a significant share of the traffic supported by the network; otherwise, the operator will have difficulties in recovering its costs.

Furthermore, at the retail level, new services, such as IPTV, when offered with traditional services are sometimes priced by the service provider on an incremental basis. The pure LRIC calculations for such services can somehow mimic this pricing approach.

In practice, as in last versions of DBA LRAIC models, pure LRIC costs will be derived by running the model twice (once with the demand for all services and once removing the demand corresponding the pure LRIC increment, e.g. the external termination traffic). Incremental costs would then be assessed as the difference between these two sets of outputs. That is, pure LRIC calculations will be similar to those carried out in the latest version of the LRAIC model.

Criterion BU 3: The LRAIC model should be able to calculate the wholesale call termination cost on the basis of the pure LRIC approach. The applied method will be similar to those done in the latest version of the LRAIC model.

2 Networks to be modelled

2.1 Scope of models and increments

2.1.1 Separation of core and access networks

Several services require an estimate of the costs of the traffic-sensitive parts of the network (e.g. fixed termination, 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).

While the core network consists mainly of active equipment, the access network consists essentially of passive equipment. The costs of the core network are generally traffic related costs whereas those of the access network generally are not.

The **costs of the core and access networks**, as traditionally defined, would give the costs of the traffic-sensitive and line-sensitive parts of the network respectively. As a consequence, core and access networks are modelled separately.

Co-location costs will be modelled separately in order to price facility sharing services.

Criterion BU 4: Access and core networks should be modelled separately.

2.1.2 The core increment[23]

Costs in the core network are driven by the volume of traffic, and to a lesser extent the number of traffic connections across the network that need to be established (a voice call being one example of such a connection), whereas costs in the access network are mainly driven by the number of subscribers. In practice, the number of subscribers and the volume of traffic will be correlated to some degree. However, it is possible to consider the implications of increasing the volume of traffic, controlling for the number of subscribers or increasing the number of subscribers, controlling for the volume of traffic.

Assets within the core network typically include:

- DLSAMs, 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.

[23] In line with DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008, Section 3.1.2.

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 modelled in the core network (see section 2.1.4).

2.1.3 The access increment[24]

As defined above, costs in the access network typically depends on the number of customers, but not the amount of traffic. Consistent with this, an alternative definition of access is that it is the service that 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. The definitions also suggest that the access network includes analogous costs for other lines, such as those for public phone boxes 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 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;
- Radio systems, cable and optical fibre 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 access model should enable to take into account the costs of the different access configurations:

- Copper and FTTC;
- FTTH and Cable TV.

Criterion BU 5: For the core network, the increment should include all services that use the core network. For the access network, the increment should include

[24] In line with DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008, Section 3.1.3.

all services that use the access network. The LRAIC of co-location is the cost incurred in providing co-location services.

These definitions include the services that the SMP operator's network division provides to its own retail division as well as services to other operators.

On the cable TV network, an end-user must typically have a TV subscription before it can have a broadband subscription. As a consequence, end-users are typically already connected to and paying for a TV service from TDC. The DBA should be able to take this into account when making regulatory decisions.

As a consequence, 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.[25]

Criterion BU 6: For the cable TV network, the model should enable to clearly isolate the cost of those assets uniquely associated with individual subscribers.

2.1.4 Scope of networks

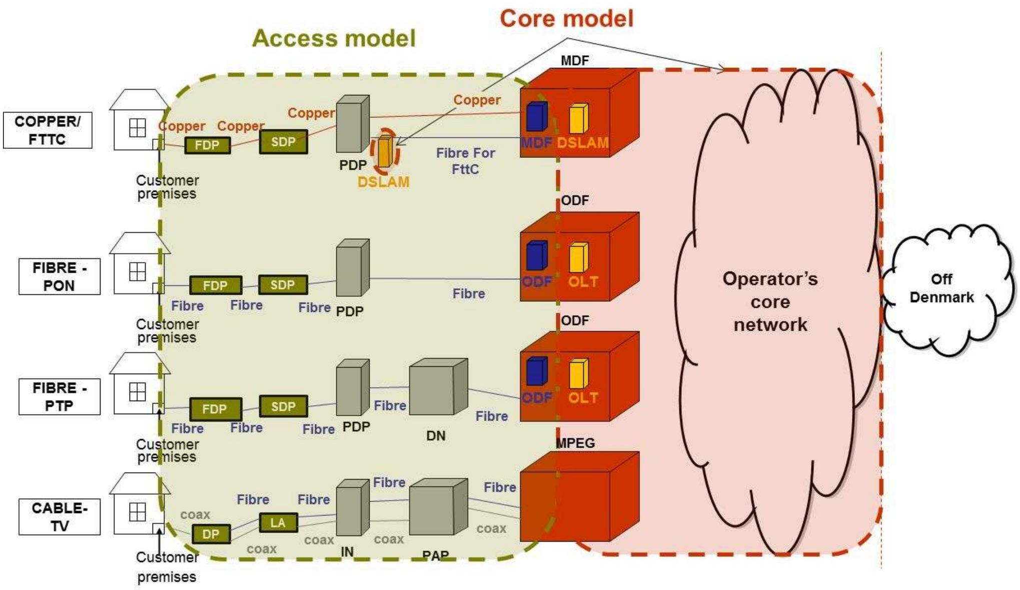
As explained in §2.1.1, access and core networks should be modelled separately. The demarcation between access and core models/networks should be set at the line card.

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 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.

Figure 3 illustrates the boundary between the two networks:

[25] In line with DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

Figure 3 : Illustration of boundary between core and access networks



Source: TERA Consultants

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 initially be calculated in the access networks cost model (to properly account for trench sharing), then trench costs should be allocated between access and core networks to be finally used as an input in the core model.

The DBA will calculate the cost of all network trenches in the access model and allocate the trench cost between the core and access networks afterwards.

Criterion BU 7: The models should include line cards in the access increment. The DSLAM located at the PCP (in the case of FTTC deployment) should be considered as part of the core network. The cost of trenches should be assessed

in the access model but corresponding costs should then be allocated between the core and access networks.

2.1.5 Other increments[26]

Other potential increments could include:

- Retail Increment: The costs referred to for the access network and core network in the previous sections are only wholesale costs. Hence, the before mentioned costs exclude any costs incurred in packaging and selling services delivered over these networks to end-users. The latter include marketing and customer billing costs, customer service costs and retail elements of the finance and human resources departments, land and buildings. These costs belong to the retail increment.
- International Increment: This increment would cover the costs of the transmission links connecting the core network to international facilities as well as the cost of those international facilities. International calls, for example, will typically use both the core increment and the international increment.
- Mobile Increment: Assets included in this increment include the base stations, base-station controllers, mobile-switching centres and transmission links using equipment solely required by the mobile network.
- Other Increment: The SMP operator may provide a range of other services such as customer premises equipment, sales, advanced data services, premium voice services, and may hold assets in overseas companies.

2.2 Services

This section describes the list of services that should be considered in the core and access networks of the LRAIC model. Since the core network is used by all three access technologies, only a single list of services is described for the core network. For the three different access networks, specific lists of services are described.

An list of services should be included within the model, since a proportion of network costs and common costs will need to be allocated to these services.

Assessing multiple services in the model increases the complexity of the calculation and the supporting data required, but is expected to result in a lower unit service costs due to economies of scope.

[26] In line with DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008, Section 3.1.4.

Criterion BU 8: The LRAIC models should include all services on the copper, cable and FTTH networks. This includes voice, broadband, TV and leased lines services.

2.2.1 Core services

The services listed for the core network are aggregated independently of the access technology. However, these services may need to be disaggregated in the LRAIC model as a given service could have different characteristics on the core network (design rule, specific platform) depending on the access technology used. Indeed, the same service provided with two different access technologies could have two different traffic flows in the core network.

Finally there are also certain services that are specific to one access technology.

2.2.1.1 Voice and Broadband services[27]

Voice services should include all the standard call services that originate and terminate on exchange lines.

Broadband services should include both broadband to own customers and wholesale (Bitstream) services.

[27] Adapted from former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

Table 1: Voice and Broadband services

Voice	Broadband
Local calls	Broadband to own customers
National calls	Bitstream access
International calls - Inbound	VULA
International calls - Outbound	Pair Bonding
International calls - Transit	IPTV over multicast
Fixed to mobile calls	VOD
Mobile to fixed calls	VOIP
IN Basic	Other services
IN Advanced	
Interconnection Transit - Within Area	
Interconnection - Transit Between Areas	
Interconnection - Local Area	
Interconnection - Within Area	
Interconnection - Between Areas	
Operator Services	
Other calls	

Source: TERA Consultants

Criterion BU 9: The models should include all relevant voice and broadband services.

2.2.1.2 Leased lines[28]

Leased lines may be classified in the three following groups according to their use:

- Retail customers, usually requiring leased lines to provide a permanent connection between customer premises;
- Other operators, usually requiring leased lines to provide a permanent connection between networks;
- Network operator itself, requiring leased lines for internal use.

[28] In line with DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

SMP operators may carry some other services, such as data services, over leased lines. Such services, for this study, should be shown separately. There should be no double counting.

Criterion BU 10: 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 as "other services".** **The models 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 are allocated to leased line services as well.**

2.2.1.3 Other services[29]

Other services use the core network such as Virtual Private Networks, Video On Demand or IPTV. These should also be included in the LRAIC model.

Criterion BU 11: The models should include all the "other services".

2.2.2 Access services

2.2.2.1 Copper access network services[30]

The access services provided over the copper network can be summarised in the following table.

Table 2: Services supported by the copper access network

Service	Service explanation
Retail voice/ broadband/ TV access	Provision of a line suitable for voice/broadband/TV respectively and sold through TDC's retail arm. One or more of these services may be provided over the same line.

[29] Adapted from former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

[30] Adapted from former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

BSA	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 TDC's network, from where the access seeker can route traffic to its own network. TDC carries traffic over the fibre line, and ensures transmission up to the access point.
Copper unbundling	Allows an access seeker to provide services, including voice and broadband, over the copper loop using its own equipment co-located with the termination block at TDC's main distribution frame (MDF). Co-location at the MDF is offered by TDC as a separate product. The unbundled cable runs from the network termination point (NTP) to a terminating block at the MDF.
Pair bonding	Access to BSA or copper unbundling using *n* copper pairs
VULA	Access to Virtual Unbundled Local Access as specified in the decision on market 4.
Ducts	Access infrastructure between a street cabinet and a net termination point
Backhaul	Access from a distribution point to a more centrally located node in the network. Relates to both ducts and active fibre infrastructure.
Leased lines	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.

Source: TERA Consultants

It should be noted that leased lines (in the copper access network) were not included in the previous LRAIC models but it is believed that in a standalone scenario, a copper network can support leased lines services, as it is observed in some European countries. Therefore, leased lines should be considered.

Criterion BU 12: The model should include all the relevant copper access services.

2.2.2.2 Fibre access network services[31]

The access services provided over the fibre network can be summarised in the following table.

Table 3: Services supported by the fibre access network

Service	Service explanation
Retail voice/ broadband/ TV access	Provision of a line suitable for voice/broadband/TV respectively and sold through TDC's retail arm. Provided over a single fibre. One or more of these services may be provided over the same line.
BSA	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 TDC's network, from where the access seeker can route traffic to its own network. TDC carries traffic over the fibre line, and ensures transmission up to the access point.
Fibre unbundling (PTP)	Allows an access seeker to provide services, including voice and broadband, over the fibre loop using its own equipment co-located with the termination block at TDC's optical distribution frame (ODF). Co-location at the ODF is offered by TDC as a separate product. The unbundled fibre runs from the

[31] In line with DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

	network termination point (NTP) to a terminating block at the ODF.
Fibre unbundling (PON)	Allows an access seeker to provide services, including voice and broadband, over the fibre loop using its own equipment co-located at/by TDC's splitter cabinet. Co-location at the splitter and transport from the splitter to the access seeker's network could be offered by TDC as separate products. The unbundled fibre runs from the network termination point (NTP) to the splitter.
Leased lines	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 the existing LRAIC model.
VULA	Access to Virtual Unbundled Local Access as specified in the decision on market 4.
Ducts	Access infrastructure between a street cabinet and a net termination point
Backhaul	Access from a distribution point to a more centrally located node in the network. Relates to both ducts and active fibre infrastructure.
Fibre access (PTP)	Provision of access to a fibre (or fibres) link between two locations. The access seeker can deploy its own electronics at these locations in order to 'light' the fibre and use for its own point-to-point transmission.

Source: TERA Consultants

It is our understanding that TDC installs and operates the necessary CPE. This is part of the BSA solution whereas it is not included in unbundled fibre access.

Criterion BU 13: 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.

2.2.2.3 Cable-TV access network services[32]

In their decision regarding market 5, the DBA mandate BSA in the cable TV network, either via the nearest L3 router in the network to the end-user, or via a central L3 router.

Therefore, the access services provided over the cable TV network can be summarised in the table below.

[32] Adapted from DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

Table 4: Services supported by the Cable TV access network

Service	Service explanation
Voice/ broadband/ TV access	Provision of a line suitable for voice/broadband/TV respectively and sold through TDC's retail arm. May be provided over a coaxial connection or a fibre pair. One or more of these services may be provided over the same line.
Decentralised BSA	Provision of a service to an end-user, where a connection of specific quality can be set up from the subscriber to the nearest L3 router in TDC's network, from where the access seeker can route traffic to its own network.
Centralised BSA	Provision of a service to an end-user, where a connection of specific quality can be set up from the subscriber to a single L3 router in TDC's network, from where the access seeker can route traffic to its own network. TDC, or perhaps another access provider, can provide transmission capacity for the access seeker to the L3 router.
Leased lines	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.

Source: TERA Consultants

It is noted that leased lines (in the cable-TV access network) were not included in the previous LRAIC models but it is believed that in a standalone scenario, a cable TV network can support leased lines services, as it is observed in some European countries. Therefore, leased lines should be considered.

It should be noted that centralised BSA can in fact be constructed from two products, namely decentralised BSA and IP transport to the central L3 router.

A significant part of the cable TV access infrastructure is owned by local broadcasting societies. TDC supplies some of these local broadcasting societies with TV signals and broadband. Today, TDC is only obliged to give access to these broadcasting societies' broadband connections when TDC is assessed to have the relevant control over the necessary frequencies for broadband distribution. The relevant control is assessed on a case by case assessment of the individual agreement.

The cost of the CPE should be included in the LRAIC model if TDC installs and operates them.

Criterion BU 14: Both bitstream services cited in the DBA's decision for market 5 will be modelled for the cable TV network. Centralised BSA will be modelled as a combination of de-centralised BSA and an IP transport product. The cost model will be capable of costing CPE and should include them if TDC installs and operates them.

Currently, the cable TV regulation is being reviewed by the DBA. The model must be able to reflect outcomes of this review.

2.2.3 Routing factors[33]

Routing factors are defined as the average frequency that a particular service uses a given network element, e.g. the number of IP routers by a broadband connection. 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 voice services, broadband services, leased lines and data services in the network on a common basis;
- in determining costs per network element/cost category and, in turn, the cost of individual interconnection services.

The unit cost per network element/cost category is simply the total cost of the element/category divided by its total volume of use, adopting a single usage driver. Where the products and services using the element/category have different units of volume, then conversion factors will need to be developed, in order to arrive at a common volume of usage for the element/category under consideration.

Routing factors may be easier to identify for some services (e.g. voice) than for others (e.g. leased lines). Alternative methodologies may need to be developed for some services to quantify their use of different elements of the core network, in a consistent and comparable way with voice services.

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 sub-local loop (from the end-user to the PDP), the routing factors corresponding to the “PDP-Exchange” segment would need to be set to zero.

Criterion BU 15: The models 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 models should also be flexible enough to allow for changes in routing factors / alternative measures.

2.3 Technologies to be modelled[34]

2.3.1 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

[33] In line with DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

[34] In line with former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

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.

Criterion BU 16: The models should only include IP packet switch technology.

2.3.2 Core transmission technologies

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

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

2.3.2.1 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.

Criterion BU 17: The models should not include SDH.

2.3.2.2 Microwave in the network

Microwave or radio relay systems are used to a small extent in Denmark to provide resilience and support to the fixed infrastructure systems (for example, when these are out of service due to upgrades).

Criterion BU 18: The models should include microwave at a small extent.

2.3.2.3 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.

Criterion BU 19: The models should not include DWDM equipment in the core network.

2.3.3 Access technologies

In Denmark, as with most countries, the line from the customer to the closest exchange usually consist 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 are provided on copper pairs, solutions have sought out to increase the amount of data/traffic that can be transmitted over a copper pair, such as xDSL technologies. Increasing data rates comes 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) are now starting to get 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 tends to be limited to business customers with large line capacity requirements. However, residential rollouts of fibre to the building have taken off. Two network architectures are 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.

Criterion BU 20: The models should include both PTP and PON network architectures for FTTH networks.

2.3.4 Degree of optimisation

Criterion BU 21: 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 SMP operator's network, and be able to provide functionality comparable to that of the existing products and services.

2.4 Evolution of demand

In the former versions of the model, the networks were dimensioned based on total demand for all services using TDC's core and access networks:

> *"The starting point when building the revised hybrid model is the level of demand in Denmark for all the services using the access and the core network of an SMP operator with a Universal Service Obligation along with an allowance for growth."*[35]

2.4.1 Access network

One of the specificities of Denmark is the presence of overlapping access networks owned by TDC. For instance, TDC's copper network is present (almost) wherever 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 are 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 §1.1.2.1) in order to send the right build/buy signals. In particular, the LRAIC approach **does not aim at re-building the network as it is today** in the reality. If the goal was to reflect the costs of the exact existing networks, then a historic cost approach would be more relevant (see §1.1.3).

[35] DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008.

Presence of several co-existing access networks in a given area is the result of history and the deployment of successive technologies. If networks were to be re-built (as assumed in the LRAIC approach), co-existence of several access networks would be highly unlikely. The presence of several access networks in parallel can indeed be considered as inefficient from a LRAIC point of view, especially since they can support same types of retail services[36]. Access networks are sometimes considered as essential infrastructures and it is therefore not desirable to duplicate such a network. For example, the European Commission stated in the context of its NGA recommendation: *"In a Fibre to the Home (FTTH) context duplication of the terminating segment of the fibre loop will normally be costly and inefficient."*[37]

Presence of several co-existing access networks is however possible during a migration phase from one technology to another.

Building the LRAIC model based on co-existing access networks in the long run would lead to artificially high access costs and would give incentives to inefficient networks duplication (wrong "build or buy" signals). It should therefore be assumed that each access network topology supports 100% of TDC's fixed demand in a given area in the long run, under the LRAIC principles.

Criterion BU 22: The LRAIC model should assume that each access network technology supports 100% of TDC's local fixed network future steady state demand in terms of active subscriptions (i.e. 100% of the "copper + cable TV + fibre" demand). Future steady state demand may differ from actual demand.

Also, the different deployment stages of all access technologies have to be considered:

- The copper network has a national coverage footprint and supports today the vast majority of active subscriptions;
- The cable TV network has reached a fairly stable coverage footprint and is highly unlikely to ever reach a national footprint. This footprint is also patchy in reality, since not all premises are passed, and not all of those passed are connected.
- The FTTH network has an on-going non-national deployment and supports an increasing number of active subscriptions.

For both copper and cable TV networks, further deployment is unlikely to happen. As a consequence, 100% of TDC's demand in the area (in terms of active subscriptions) can be considered from the start. For FTTH, same assumption should be followed but a risk premium should be added in the calculation to take into account the specific risks incurred by FTTH operators such as the risk of not having 100% of the demand from

[36] See § 2.2.2.

[37] European commission, NGA Recommendation, 20 September 2010.

the start (see §0) and therefore send appropriate "build or buy" signals. However, the risk premium should be reasonable since one alternative operator would probably not invest in FTTH if the risk was too high and second because TDC can mitigate this risk as it has the ability to migrate its cable TV and copper customers to FTTH.

In the access network, not all premises have an active subscription enabling operators 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 only by connecting active customers would be highly inefficient in the long run. As a consequence, access networks in the LRAIC model should be dimensioned by connecting all premises of the area they cover.

However, costs should be recovered over the subset of connected locations assumed to have an active subscription.

In the case of cable TV areas, costs should be recovered over the subset of connected locations assumed to have an active subscription (i.e. paying for TV services at minimum).

Criterion BU 23: The cost of passing all the premises within an area should be modelled. Corresponding costs should be recovered over the subset of connected locations assumed to have an active subscription.

2.4.2 Core network

The core network should aggregate the demand from all the services using one of the three access networks **in TDC's network:**

- Copper;
- Cable TV;
- FTTH.

This is the same approach as the previous LRAIC model and reflects a situation where the core network is agnostic from the access network technology being deployed.

Criterion BU 24: The starting point when building the LRAIC model for the core network is the level of demand in TDC's network for all the services using the copper, cable TV and fibre access networks.

3 Types of costs and cost allocation

There are two dimensions in categorising costs when considering fixed- and mobile 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.

Figure 4: Different types of costs for a telecoms network and examples

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

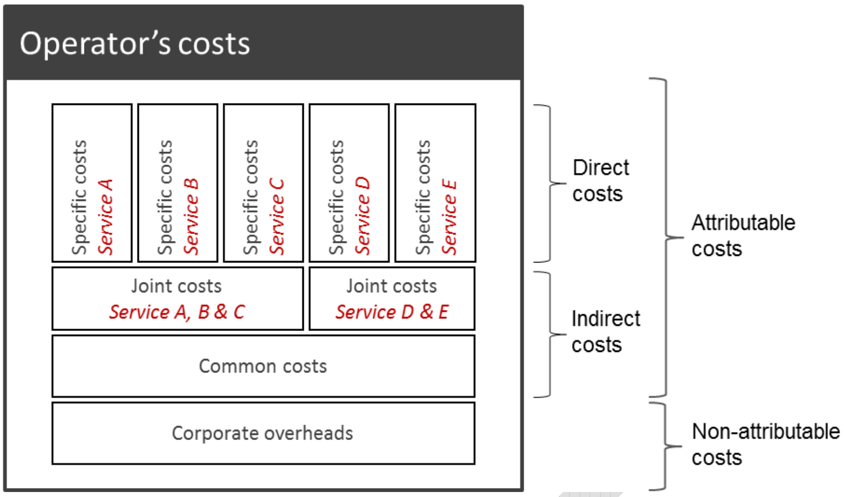
Source: TERA Consultants

3.1 Direct, Indirect 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 non-attributable costs consist of only corporate overheads. Indirect costs consist of joint and common network costs[38].

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

Figure 5: Different types of costs in an operator's costs



Source: TERA Consultants

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 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*.
- **Network common costs**: these costs are incurred when producing all services. As in joint costs above, network common costs are indirectly attributable. They have an unambiguous causal relationship with *all 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.

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. In electronic communications 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 (voice 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 will present various cost allocation approaches for indirect costs and the special case of corporate overheads.

3.1.1 Allocation of indirect costs: joint and network common costs allocation

Different allocation keys can be envisaged for the allocation of indirect 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 and the Shapley-Shubik rule are the rules that are generally considered and used by regulatory authorities for allocating joint and common network costs. These two approaches have the advantage of being more easily implementable in a bottom-up model. They are presented hereafter:

- **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[39]. This rule is the one traditionally used by the DBA as it follows the cost drivers (networks are dimensioned to support the peak of traffic). This rule tends to allocate a large share of indirect costs to services that load the network a lot (data, Internet or VoD), but leads to low unit cost for services that load the network (voice services) less. As the traditional rule, the capacity-based allocation rule should be implemented in the model.

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

- **The Shapley-Shubik allocation rule**[40] consists of setting the cost of a service equal to the average of the incremental costs of the service after reviewing every possible order of arrival of the increment (see example below). Such a rule may be worth considering because it gives different insights as compared to the traditional rule. For example, with the capacity-based allocation rule, voice services are often allocated a very small share of common network costs because they use much less capacity compared to other services. Therefore, voice services may bear very low costs, which could contrast with the value of the voice services as perceived by market players and consumers. In such a case, the Shapley-Shubik allocation rule may provide a more appropriate outcome. This allocation rule however presents two difficulties:
  - First of all, it is necessary to define the relevant increments. There can be different ways to define the increments. In general, in order to simplify the approach, broad increments are generally considered such as: voice service increment, broadband increment, IPTV increment and leased lines and data services increment. With such broad increments, traditional allocation approaches can still be needed to calculate costs of smaller services (for example for call origination within the voice increment).
  - Second of all, this rule requires running the LRAIC model several times (for example, 6 times if there are 3 increments and 24 times if there are 4 increments). This is also why it is preferable to define broad increments.

[40] The Shapley-Shubik rule has also been considered by some NRAs such as ARCEP in France (decision 2008-0896) or ComReg in Ireland (decision D03/08).

Figure 6: Shapley-Shubik allocation in the case of a network supporting two services (voice and data)

- Let us consider a network supporting voice and data. The standalone cost of voice is 75 and 80 for data. The total cost of the network is 100.
- For this 2-service Network, 2 sequential scenarios are possible:

Scenario 1	Scenario 2
1st investment VOICE 75	1st investment DATA 80
2nd investment DATA 25	2nd investment VOICE 20

- The cost allocation is then completed as follows (47.5% to voice, 52.5% to data):

	Voice	Data	Total
Scenario 1	75	25	100
	+	+	+
Scenario 2	20	80	100
	=	=	=
Sum	95	105	200
%	*47.5 %*	*52.5 %*	*100%*

Source: TERA Consultants

Criterion BU 25: Both the capacity-based and the Shapley-Shubik allocation rules for joint and common network costs should be implemented in the LRAIC models.

3.1.2 Allocation of 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[41]. According to BEREC, the method traditionally used by NRAs to allocate these costs is the EPMU approach[42]:

> *"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)."*

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

[42] ERG - Recommendation on how to implement the commission recommendation C(2005) 3480 – 2005.

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.

Table 5: Numerical example of the EPMU method (for illustrative purpose only)

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%

Source: TERA Consultants

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[43].

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

Criterion BU 26: Corporate overheads costs should be allocated on the basis of the EPMU approach.

3.2 CAPEX assessment

CAPEX are costs incurred when a telecoms operator invests in equipment and/or designs and implements the network infrastructure. The equipment includes for

[43] "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.

example the DSLAMs, the routers, the switches, and the entire core network equipment, whereas the costs for the design and implementation of the network infrastructure can be site acquisition and civil works.

In the LRAIC model, CAPEX are derived from the service demand through engineering principles.

3.2.1 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.

Moreover, an SMP operator could be expected to have stronger bargaining power than other operators. The models should take this into account.

Criterion BU 27: Prices used in the models should reflect those that an efficient operator with the bargaining power of an SMP operator would face.

3.2.2 Base Year

The base year, the year to which all data should be related, is 2014. If data for one reason or another is not available for that specific year, an extrapolation should be made from relevant historic data to calculate the proper reference data for the base year.

Criterion BU 28: The models should model the costs for 2014. In subsequent years, the base year of the model will be adjusted accordingly.

3.2.3 Replacement Cost

As LRAIC models are forward looking, current costs will be the appropriate cost basis. One way to estimate current costs is to calculate the replacement cost of each asset. The replacement cost can be higher or lower than the historic cost.

According to the Price Control Order, the Modern Equivalent Asset (MEA) approach is the accepted approach to estimating replacement costs:

> *"(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****."*[44]

In the MEA assessment document[45], the MEA concept is defined as *"the asset that a new operator taking efficient decisions would take today to deploy a new network"*.

General purpose properties such as office buildings are typically valued on an open market valuation basis (either for existing or alternative use).

For properties in general, the approach previously developed by the DBA should be adopted. With this method, the public property values as informed by TDC are adjusted by a factor representing the difference between the market price and the public valuation in each geographical area. This includes special purpose properties used to house technical equipment such as switches, routers, remote concentrators and DSLAMs and general purpose properties such as office buildings. However, if buildings are rented, the renting costs should be included as an operational cost.

Criterion BU 29: The models should use a Modern Equivalent Asset concept to estimate current costs. Replacement cost in the model should correspond to the cost of buying new equipment in the base year.

For properties in general, the building costs should be valued in accordance with the method previously developed by the DBA. With this method, the public property values are adjusted by a factor representing the difference between the market price and the public valuation in each geographical area

3.3 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;

[44] Source: DBA Executive Order on Price Control Methods, Section 3, dated 27 April 2011.

[45] Source: DBA, Final MEA assessment, April 2013.

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;

Table 6: Numerical example of top-down assessment with efficiency adjustments (for illustrative purpose only)

Cost of faults: • 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**

c. **Bottom-up assessment (based on a percentage of capital cost):** This approach uses percentages provided by suppliers of telecoms electronic equipment[46]. 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.

Table 7 : Numerical example of bottom-up assessment based on necessary employees

Access infrastructure management: • Minimum staff: 10 FTE • +1 FTE per 2 MPEG stations • 30 Mpeg stations

[46] 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).

- 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

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 involve 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. As a consequence, operating costs should be calculated using these approaches depending on their feasibility (e.g. information availability). **As a starting point, similar approaches as the ones implemented in previous models should be used.** However, the following choices are anticipated:

- **Pay costs** should be estimated using a bottom-up assessment based on necessary employees (approach d);
- **Maintenance costs** should be calculated using the bottom-up assessment based on a percentage of capital cost (approach c) or the top-down assessment with potential efficiency adjustments (approach b). In the specific case of access networks, a comparison of Line Fault Index (LFI) of existing networks (copper, cable TV) with LFI of new networks (LFI of a new copper built or new cable TV network or FTTH network) should be performed. As maintenance costs tend to be proportionate to a very large degree to the LFI and as the LRAIC models calculate the costs of new networks, the observed difference in LFI could be used to calculate relevant LRAIC maintenance costs ;
- **Energy, cooling and building costs** should be calculated with a true bottom-up approach (approach e).

A top-down approach for the calculation of OPEX (approach a) is not consistent with the principle of the bottom-up approach as inefficiencies and irrelevant cost may be included. The benchmark approach (approach f) is not country-specific and may lead to under-estimated / over-estimated OPEX in the context of Denmark. As a consequence this approach should be used only in case operators' data is unavailable. Even where operator data is available, benchmarked data can be used as a cross-check of the resulting OPEX estimates.

Criterion BU 30: Operating costs should be calculated using one of the following approaches depending on their feasibility (e.g. information availability): Top-down assessment with potential efficiency adjustments, bottom-up assessment based on a percentage of capital cost, bottom-up assessment based on necessary employees, true bottom-up assessment.

3.4 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 s 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 (see a proxy of the economic depreciation in §3.4.1.3).

Three traditional annuities formulas will be presented in this section: the standard annuity (§3.4.1.1), the tilted annuity (§3.4.1.2) and the full economic depreciation (§3.4.1.3).

3.4.1.1 Standard Annuity

The use of this method is appropriate when asset prices and volumes of outputs produced by this 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:

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

Then, *A* can be written as follows:[47]

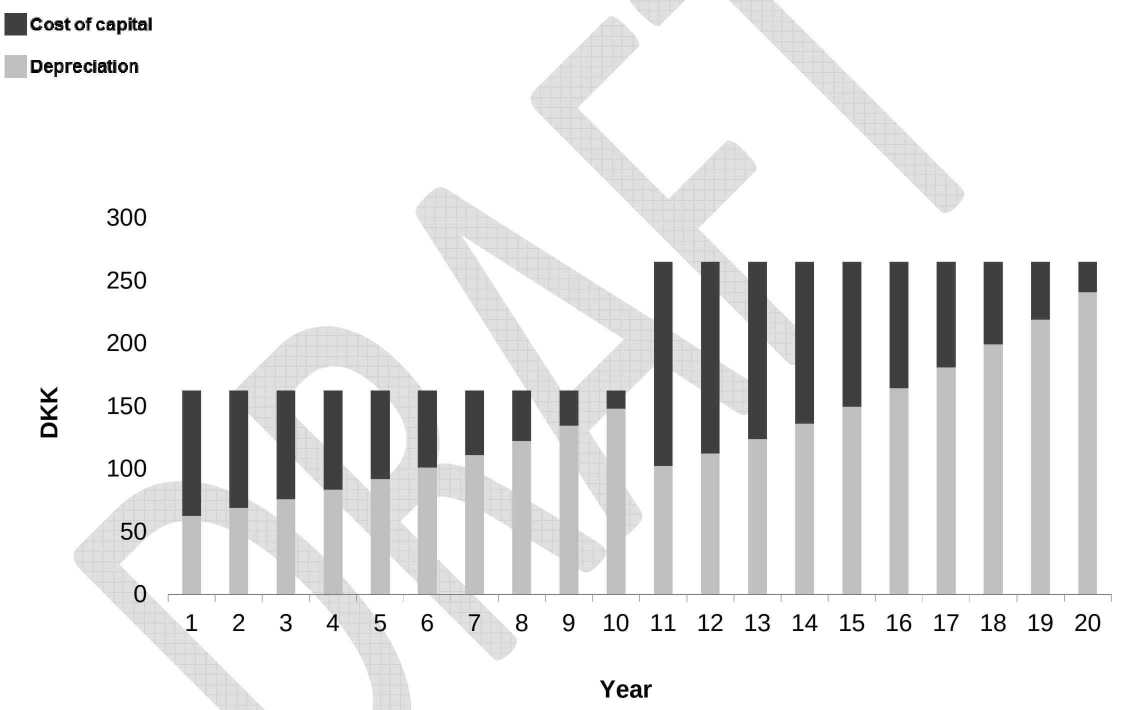
[47] This formula assumes that the operator begins generating revenues from the asset one year after investment is completed.

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

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

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.

Figure 7: Asset renewal (year 11) at a higher price under standard annuity method (discontinuity)

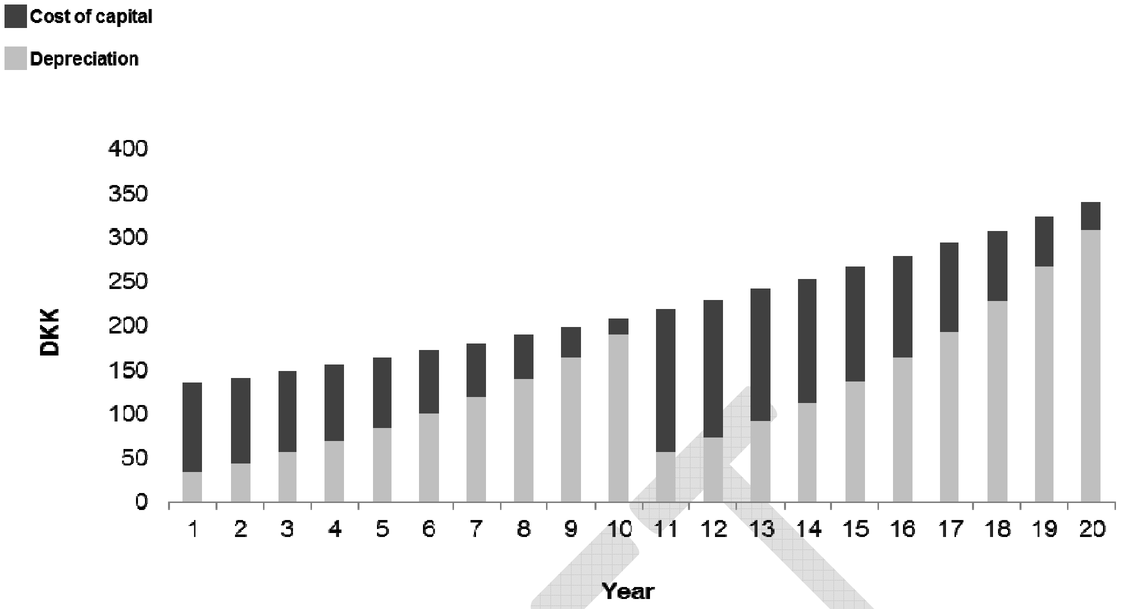


Source: TERA Consultants

3.4.1.2 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 the figure 8 below. 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.

Figure 8: Annuities with the tilted annuity method - Asset renewal (year 11) under tilted annuity method – Asset price increase of 5% per annum (continuity)



Source: TERA Consultants

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

$$I = \frac{A_1}{(1+\omega)} + \frac{A_1 \times (1+p)}{(1+\omega)^2} + \ldots + \frac{A_1 \times (1+p)^{n-1}}{(1+\omega)^n}$$

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[48]. This

[48] 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 $(1+\omega)$).

formula is derived by the same equation as the one provided in the beginning of this section[49] but with the following relationship between each annuity:

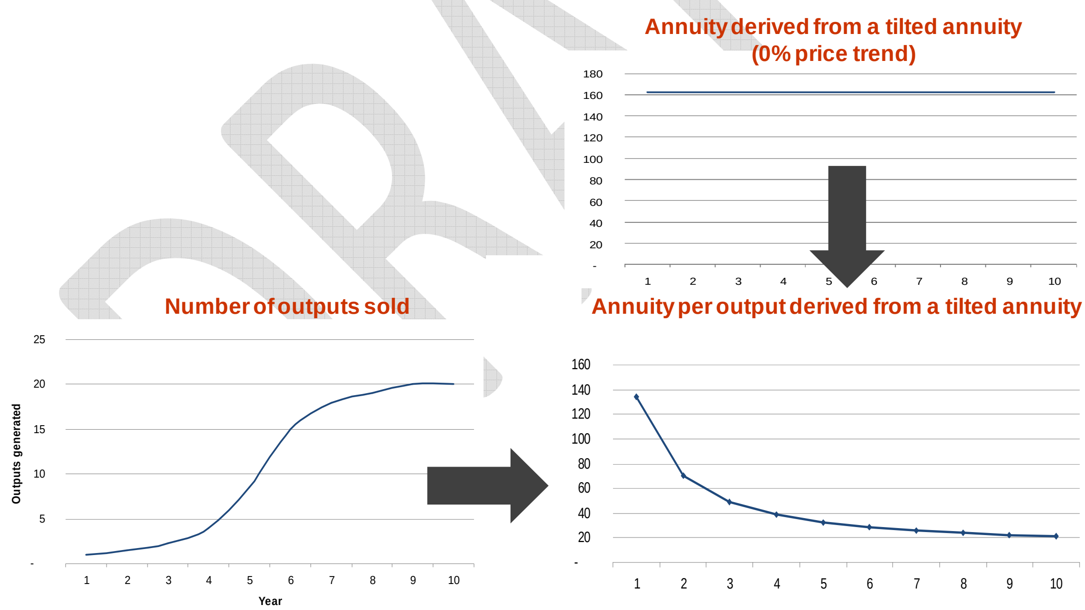
$$A_t = A_{t-1} \times (1 + p)$$

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 figure 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 products (which have a logistic curve) or when demand is evolving fast (see example below).

Figure 9: 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: TERA Consultants

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

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

3.4.1.3 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 the constant annuity A_1 is replaced by CxNi where C is constant and Ni varies in the same way as the number of outputs.

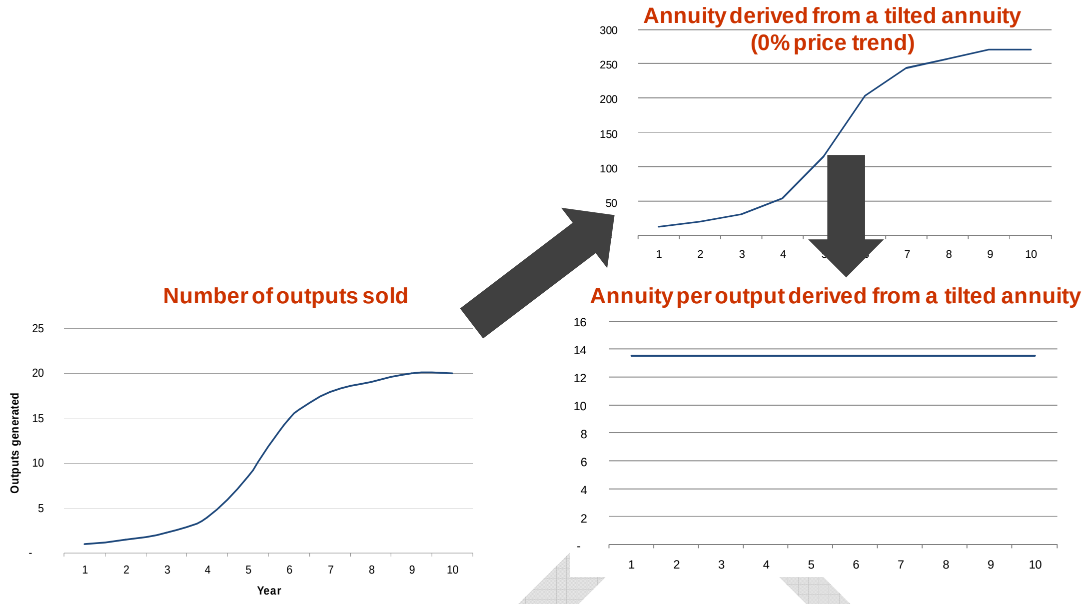
Let *I* be the investment, *C* the constant unit cost, *p* the tilt (price trend of asset) and N_i the number of outputs sold in year *i*. The investment can be computed as follows:

$$I = \sum_{i=1}^{n} \frac{A_i}{(1+\omega)^i} \quad \text{becomes} \quad I = \sum_{i=1}^{n} \frac{C \times (1+p)^{i-1} \times N_i}{(1+\omega)^i}$$

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

Figure 10: Annuities (depreciation charges plus return on capital employed) under the full economic depreciation method



Source: TERA Consultants

By taking in 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 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.

Criterion BU 31: Tilted annuities and full economic depreciation (where volumes of outputs can change significantly) should be used in the LRAIC model. However, as in the access network, demand is supposed to be stable (see § 2.4.1), tilted annuities will only be implemented.

3.5 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 modelling 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.

The possibility to have four different WACCs for the different networks to be modelled should be included (as level of risk can be different for the different networks): :

- a copper access network WACC;
- an IP core network WACC;
- a fibre network WACC;
- a cable-TV network WACC.

This is consistent with previous LRAIC models[50]:

Criterion BU 32: The LRAIC model should include the facility for separate WACCs for the core, copper, cable TV and fibre networks. A review of the cost of capital to be applied as part of the pricing decisions will be undertaken and will be issued for consultation to industry as part of this process.

In the specific case of a fibre access network, the WACC will need to be derived with reference to the European Commission Recommendation on regulated access to Next Generation Access (NGA) networks[51] and subsequent updates to that document. Of particular relevance is Annex I, which sets out principles for assessing risk (and the risk premium) in network deployments. These principles would feed into the calculation of particular parameters for the WACC calculation, such as the beta.[52]

The risk premium should be able to factor the specific risks taken by operators investing in NGA (such as financial costs related to demand take-up, see §2.4.1).

Criterion BU 33: The LRAIC model should have the possibility of including a risk premium for NGA networks.

[50] See DBA (NITA at the time), Final Model Reference Paper, 3 September 2010, Criterion CG15.

[51] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:251:0035:0048:en:PDF

[52] As in DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

3.6 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". It consists in the net balance of operating uses and sources of funds, which can be either positive or negative[53]. On a day-to-day basis, there can be a delay between the day a cost is incurred and the moment the revenues aimed at recovering this cost are generated. As an example, there will always be a delay between the day an additional mobile base station is acquired, and the day the mobile operator will earn extra revenues deriving from the extra traffic generated by this base station.

The working capital can generate revenues (through interests) when positive. But it can also generate financial costs for the operator when negative. These revenues and financial costs may need to be taken into account in cost models. The cost of the working capital is equal to the capital employed multiplied by the weighted average capital cost, or WACC (see below for further explication on the WACC).

An electronic communications operator faces different types of costs that can generate working capital:

- Network CAPEX (see §3.6.1);
- Network OPEX (see §3.6.2).

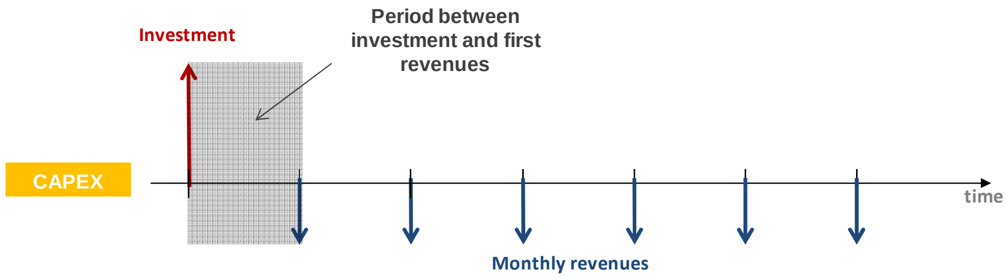
The issues of working capital generated by these costs are discussed in detail below.

3.6.1 Working capital by network CAPEX

When making network investments, an operator generally begins earning revenues from its asset several months after the investment is completed (the generated cash can then be used to reimburse shareholders and banks). This period which goes from the payment of an asset to its first operating use generates working capital and is sometimes referred as "time to build" (the "time to build" period can vary significantly from one asset to another). "Time to build" periods are usually taken into account in cost models.

[53] Formally, net working capital is equal to current assets (cash and cash equivalent, accounts receivable, inventories and short term investment) minus current liabilities (accounts payable and the current portion of long term loans).

Figure 8: Network CAPEX and working capital (for illustrative purpose only)



Source: TERA Consultants

For network CAPEX, working capital is therefore linked to the "time to build" period that exists between network investment payment and the beginning of network revenue. For instance, if there is a one month delay between the time the investment is completed and the time that revenues are generated, then it is necessary to take into account the monthly cost of capital (i.e. multiply the annuities by the monthly WACC). This can be done easily by multiplying each annuity by $(1+ \text{WACC})^{\text{time to build (in years)}}$.

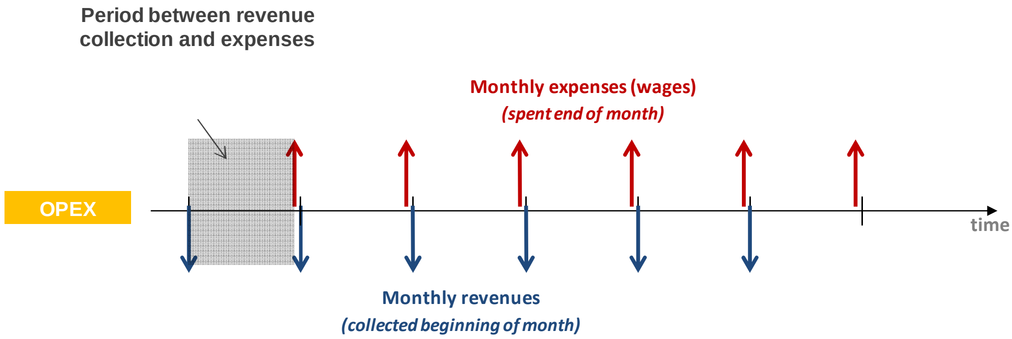
The depreciation formulas (tilted annuity or full economic depreciation formula) presented above **already includes a network CAPEX working capital** corresponding to a 6-month "time to build".

3.6.2 Working capital by network OPEX

For operating costs**,** there can also be a period of time between staff and suppliers being paid and revenues being earned. Two situations can thus be anticipated:

- Staff and suppliers are paid before revenues are earned: the working capital is negative and the company incurs a cost;
- Staff and suppliers are paid after revenues are earned: the working capital is positive and the company earns a profit.

Figure 9: Network OPEX and working capital (for illustrative purpose only)



Source: TERA Consultants

Most of the time, staff and suppliers are paid at the end of the month whereas revenues are perceived at the beginning of the month. As a consequence, network OPEX working capital is considered to be positive or at least balanced. It seems therefore reasonable not to take it into account. This is consistent with overseas approaches[54].

Criterion BU 34: Except for working capital generated by CAPEX which should be taken into account through depreciation formulas, the cost of working capital related to network OPEX should be excluded from the LRAIC model.

[54] In its LLU and sub-loop unbundling (SLU) decision in 2009, ComReg undertook some benchmarking of the treatment of working capital in several international cost models including Australia, France and Sweden. ComReg concluded that in these countries the cost of working capital has been set to zero (ComReg – Decision 0939).

4 Models implementation

4.1 Modelling Guidelines

The bottom-up model should produce LRAIC estimates for exchange of voice and data traffic, access lines and co-location 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 four steps:

- Estimating demand;
- Equipping the hypothetical network, both in terms of assets and operating activities, to serve the measured increments at lowest cost;
- Determining the costs of the network; and
- Costing the services under scrutiny.

4.1.1 Estimating Demand[55]

The core and access increments include all services that use the core and the access network. The relevant measure of demand for these services, defined as end-user demand (internal and external), is the current level of demand along with an allowance for growth.

Criterion BU 35: The starting point when building the bottom-up model is the level of demand in Denmark for all the services using the access and the core network of an SMP operator along with an allowance for growth.

4.1.2 Equipping the Network

Engineering principles will inform the dimensioning process for direct network cost categories. For example, the number of ports in a router might be estimated by reference to the busy hour traffic (measured in either bits per second or packets per second as appropriate) flowing through the particular router.

Other cost categories will be required to provide functionality to direct network cost categories. These are referred to as indirect network cost categories. So, for example,

[55] In line with DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

the number of racks at an exchange site (a scorched node) may be estimated by reference to the direct network equipment located there.

4.1.3 Costing the Network

In the LRAIC model, both unit costs of equipment and the operating and indirect costs associated with the different types of equipment are included. Using this information, total investment costs for the network can be estimated. However, the model also needs to calculate annual costs, so the investment costs will need to be annualised to generate an annual figure for the capital expenditure involved with using each asset. Operating costs and corporate overheads should be calculated in accordance with §3.3 and §3.1.2. The intention should be to take the existing approach within the existing LRAIC model as the starting point with regard to the treatment of operating costs.

4.1.4 Costing Services

The final step in the process will be to calculate the costs for various products 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 products.

4.2 Optimisation in the LRAIC Model

4.2.1 The Scorched Node Assumption[56]

The 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.

However, the structure of the network to be modelled should be in line with the outputs of the Market 3 decision and upcoming Market 2 decision as regards the number of points of interconnections (PoI) to be considered. In this specific case therefore, it could be necessary to depart from the Scorched Node constraint.

Criterion BU 36: The LRAIC model should show the costs of a network with an efficient configuration operated by an efficient company, based on the latest

[56] In line with former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

proven technological solutions and an optimally structured organisation. However, the starting point should be the existing geographic network architecture in the SMP operator's network. This implies that equipment should be placed at the existing geographical locations of the SMP operator's network nodes (the scorched node assumption).

Outputs of the Market 3 decision and the upcoming Market 2 decision should be taken into account when the network topology is modelled.

The following list of equipment meets the basic definition of a node within an all-IP network:

- 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.

An efficient operator is also likely to have a number of other types of equipment in their network, such as Soft switches and Media Gateways. These may also need to be included in the LRAIC model where they are necessary for the services.

4.2.2 Guidelines on Optimisation[57]

Although the core increment has been defined broadly to include all of the services using the core network, these services historically tended to use different types of equipment. For example, PSTN traffic tended to be carried over a circuit switched network, whereas broadband traffic would be carried over a packet switched network. However, with the move towards so-called Next Generation Networks (NGNs), there is convergence in the way that traffic is carried such that it all tends to traverse an all-IP, packet switched, network. For this reason, the LRAIC model should utilise a network based on packet switched, IP, technology. This is the technology implemented in the previous model.

One important issue with the adoption of a packet switched network is that, from the end-user's perspective, the overall quality and functionality of voice traffic should remain the same as it was when carried over a circuit switched network. Thus, the quality level, functionality and other characteristics of the modelled network should correspond to the voice interconnection products that the SMP operator's network is designed for, so that the integrity of the electronic communications services and interoperability is upheld.

[57] In line with DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

The modelled network must be technically feasible. The network must not be too theoretical or experimental, but should reflect the type of network that would be rolled out or developed by operators who were to build a national network today.

However, the structure of the network to be modelled should be in line with the outputs of the Market 3 decision and the upcoming Market 2 decision as regards the number of points of interconnections (PoI) to be considered. In this specific case, it could therefore be necessary to depart from the Scorched Node constraint.

Criterion BU 37: The LRAIC model should utilise a technically feasible network based on packet switched, IP, technology. The quality level, functionality and other characteristics of the modelled network should however correspond to the voice interconnection products that the SMP operator's network is designed for.

Outputs of the Market 3 decision and the upcoming Market 2 decision should be taken into account when in the network topology to be modelled.

The optimised network must be able to meet the dimensioned demand (traffic). In practice, this means that the model must be able to show:

- That equipment is dimensioned sufficiently to carry all subscriber lines;
- That equipment is dimensioned sufficiently to carry all of the relevant traffic taking account of the busy hour (for both voice and data traffic), blocking margins, and contention levels; and
- That the network has been dimensioned with sufficient resilience.

Criterion BU 38: The model must be able to demonstrate that the optimised network can carry the dimensioned traffic with a sufficient level of resilience.

One of the most important requirements of the optimised network is that it provides services at an appropriate quality of service. The traditional circuit switched voice networks have proved to be highly reliable and have offered very good quality of service (QoS). Packet-switched networks are very efficient in transporting data, but care must be taken to ensure that real time services such as voice telephony do not suffer in quality, particularly from an end-user perspective.

Quality of service can mean, among other things:

- Grade of service or blocking margin
- Resilience
- Speech quality
- Transmission delay

- Jitter

Criterion BU 39: The LRAIC model needs to demonstrate that the optimised network provides services at a level of quality and functionality, which as a minimum meets the level that the SMP operator offers today to interconnecting operators and end-users.

Even though the LRAIC model will be based on a packet switched core network, it will still need to interface with more traditional circuit switched networks owned by other licensed operators. For this reason, the modelled network must incorporate necessary additional equipment, such as Media Gateways, to facilitate traditional PSTN interconnection products. As explained in the final MEA report, the LRAIC model should be able to model also IP-IP interconnection.

Also, the structure of the network to be modelled should be in line with the outputs of the Market 3 decision and the upcoming Market 2 decision as regards the number of points of interconnections (PoI) to be considered. This should be taken into account for example when setting the number of Media Gateways.

Criterion BU 40: Although the model will be based on an "all-IP" network, it will still need to interconnect with TDM networks. Thus the costs of interconnecting with such networks (media gateways) should be included as well as IP-IP interconnection elements.

Outputs of the Market 3 decision and the upcoming Market 2 decision should be taken into account when setting the number of Media Gateways.

4.3 Modelling Access

Access network cost models are fundamentally different from fixed core network cost models. This is due to the fact that passive assets are predominant (especially for copper local loops) and civil works costs are major costs. The steps of the development of this type of model are therefore significantly different. In particular, geographic and demographic data is a key input for this type of LRAIC models.

The models will be developed using Microsoft Access database software for static calculations and Microsoft Excel for calculating the results. As described in §4.3.2.2, the access network 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, contrary to previous models, Microsoft Access. However, to facilitate the understanding of the costing of the network, Microsoft Excel will be used for all other purposes, e.g. to calculate results.

Criterion BU 41: The LRAIC access network cost model will be based on both Microsoft Access and Microsoft Excel but Microsoft Access should be used to a minimum extend to facilitate the review and understanding of the LRAIC model by stakeholders.

4.3.1 Estimating Demand

The main source of information on the current level of demand in Denmark will be the SMP operator, today TDC. The model should include the demand for services listed in §2.2.2, including those offered by other operators to end customers via the SMP operator's network. Forecasts on the future levels of demand will be required, for example because core networks are generally dimensioned by taking into account future demand. For access networks, the level of demand has very limited impact on the network dimensioning (that is rather based on the number of premises). However, the level of demand would be required to derive unit costs.

Criterion BU 42: The LRAIC model should be capable of handling demand forecasts for the relevant services.

4.3.2 Equipping the 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:

- Collecting geomarketing data;
- Rolling out the networks; and
- Dimensioning the networks;

These phases are described in the sections hereafter.

4.3.2.1 Geomarketing data[58]

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

[58] New criteria compared to former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

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 SMP operator These nodes are:

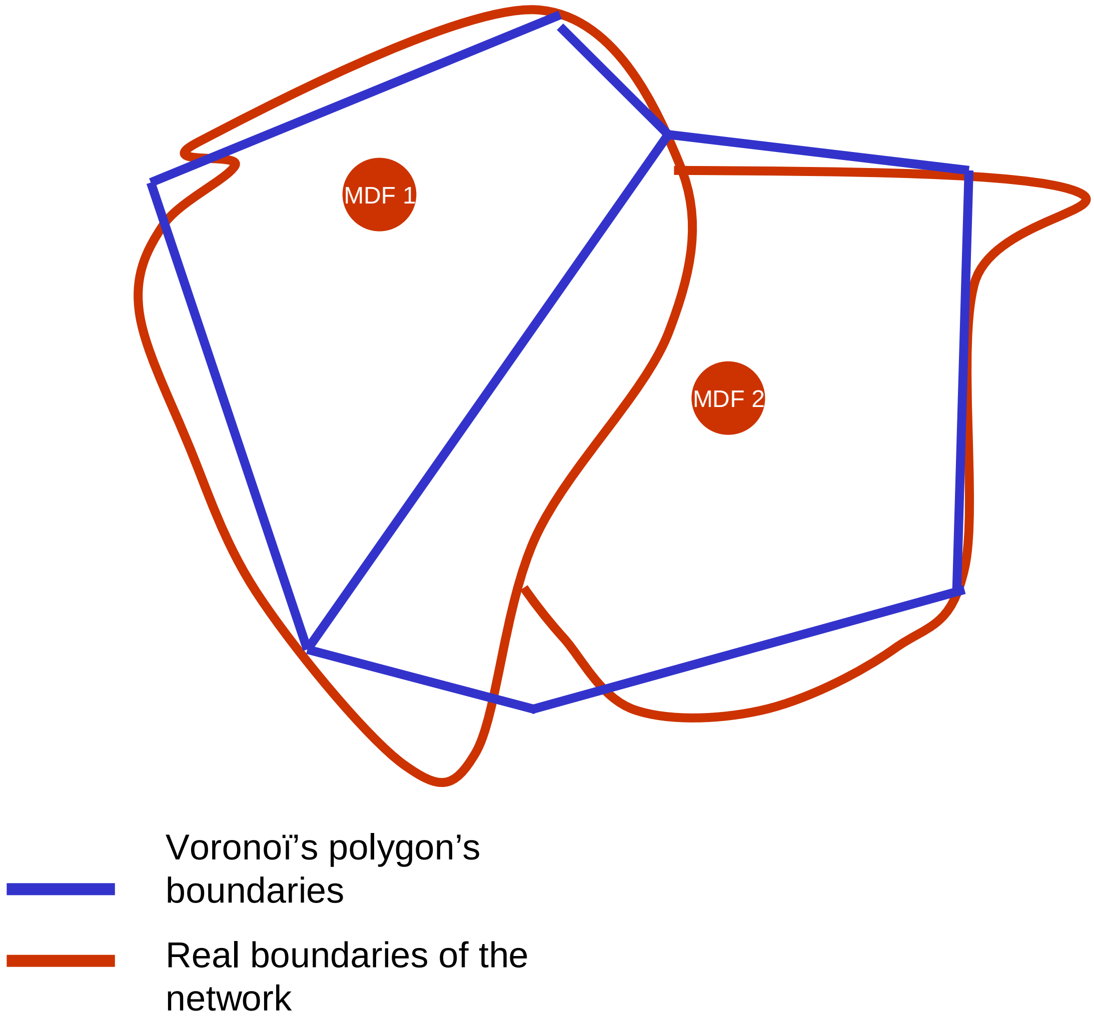
- The MDFs for the copper access network;
- The ODFs for the FTTH access network;
- The MPEG stations for the cable-TV access network.

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. These coverage areas should be based on operators' data, in accordance with the scorched node approach. They are generally available in Shape file format.

In case these coverage areas are not available, it is possible to use a theoretical split of the country (still using the nodes of the operators) using the Voronoi decomposition. The Voronoi approach, if used, 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[59].

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

Figure 11: 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: TERA Consultants

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;
- The Primary Access Points, the Island Nodes and the Last Amplifiers in the cable TV network.

Criterion BU 43: The LRAIC model should use as much as possible locations (X;Y geographic coordinates) and coverage areas of each network node of the operators.

These coverage areas, grouped together, create the full network coverage:

- As the copper network has been deployed decades ago by TDC and since new copper deployments are limited (because it covers the full Danish territory), TDC's copper coverage areas should be used.
- The cable TV network coverage area should be the area where TDC has rolled out the cable TV network.
- For the FTTH network, several options are possible, as it has not been fully deployed by TDC. The coverage area of the FTTH network could be:
    - Option 1: The coverage area of the copper network. This was the case in the previous versions of the LRAIC model;
    - Option 2: As fibre cables are increasingly being rolled out in the cable TV network and are getting closer to the customer premises[60], it is not unreasonable to expect that in the medium to long term the cable TV network is becoming very similar to a FTTH network. Therefore, the coverage areas of the fibre network could be those of the cable TV network where there is cable TV and those of the copper network where there is no cable TV today. However, it remains necessary to determine whether ODFs are located at similar locations as PAPs or at similar locations as MPEG stations. It appears that MPEG stations coverage is significantly larger than ODF or MDF coverages and therefore, it is more reasonable to assume ODFs are located at PAP locations;
    - Option 3: Actual and future areas where TDC and utilities companies plan to roll out a FTTH network could also be used.

In the MEA paper it is proposed to model the passive part of FTTH and cable TV on the same basis to simplify the LRAIC model. Therefore, option 2 is preferable. Hence, the link between the MPEG station and the PAP is included in the model in order to calculate the cable TV network costs properly. By choosing option 2, two access models would have to be developed.

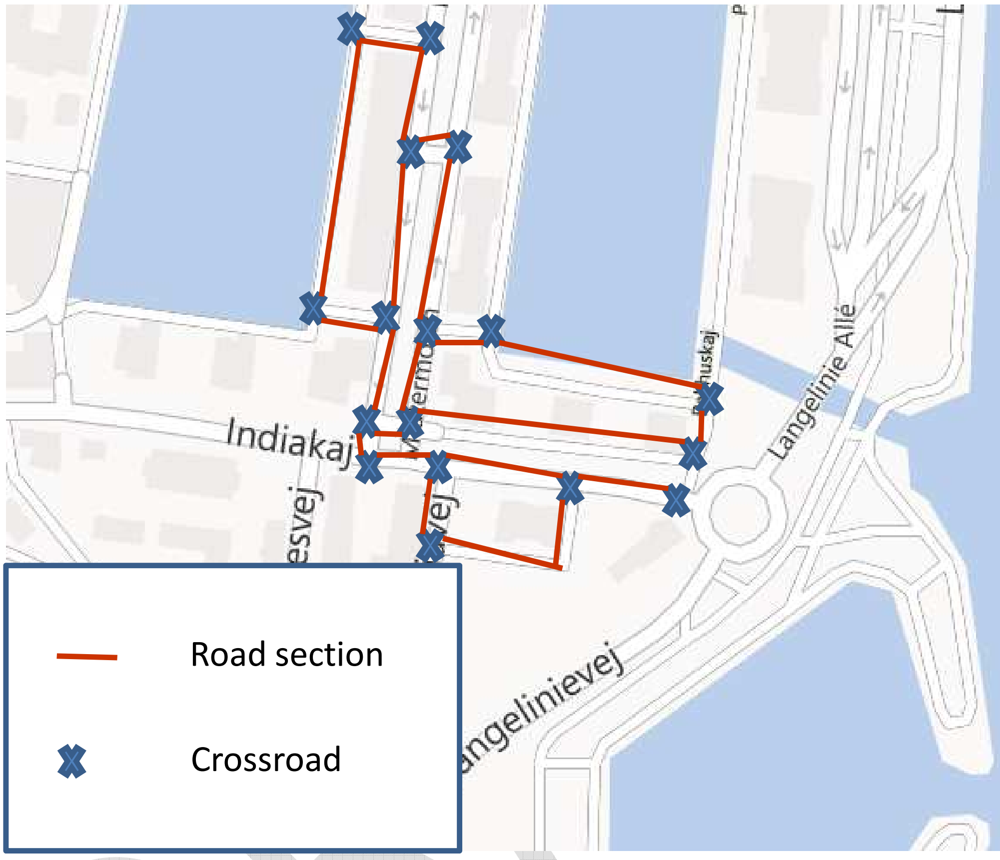
Criterion BU 44: The model should use the coverage areas of: TDC for the copper network, TDC for the cable-TV network and TDC's cable TV for the FTTH network (and copper network outside cable TV areas).

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.

[60] Source: YouSee's response to the previous data request.

The road network data should be collected from GPS data providers such as Navteq or TomTom/TeleAtlas. 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.

Figure 12: Example of road sections (all are not highlighted in red) in Copenhagen



Source: TERA Consultants

Criterion BU 45: The LRAIC model should use the road network database provided by a GPS data provider.

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.

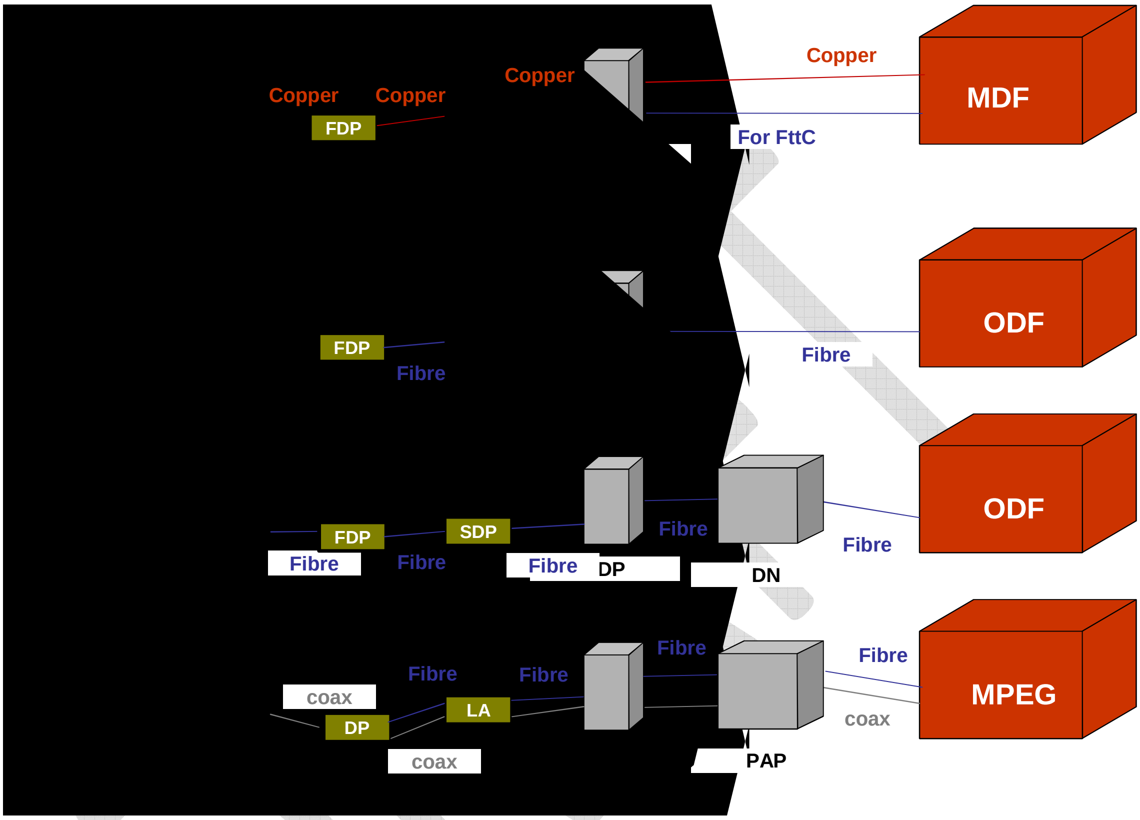
The building data should be collected from KMS databases. This was used in the previous revision of the LRAIC model.

Criterion BU 46: The LRAIC model should use the data on buildings provided by KMS or equivalent sources if not available.

4.3.2.2 Roll-out of the network[61]

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

Figure 13: Networks architecture[62]



Source: TERA Consultants

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";
- 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".

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[61] New criteria compared to former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

[62] 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 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 five parts:

- The part between the ODF and the DN (Distribution Node);
- The part between the DN 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 four parts:

- The part between the MPEG station 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”.

Criterion BU 47: The LRAIC model should use the operators’ networks hierarchies.

The network roll out is carried out by first connecting the main node to the primary sub-nodes 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.

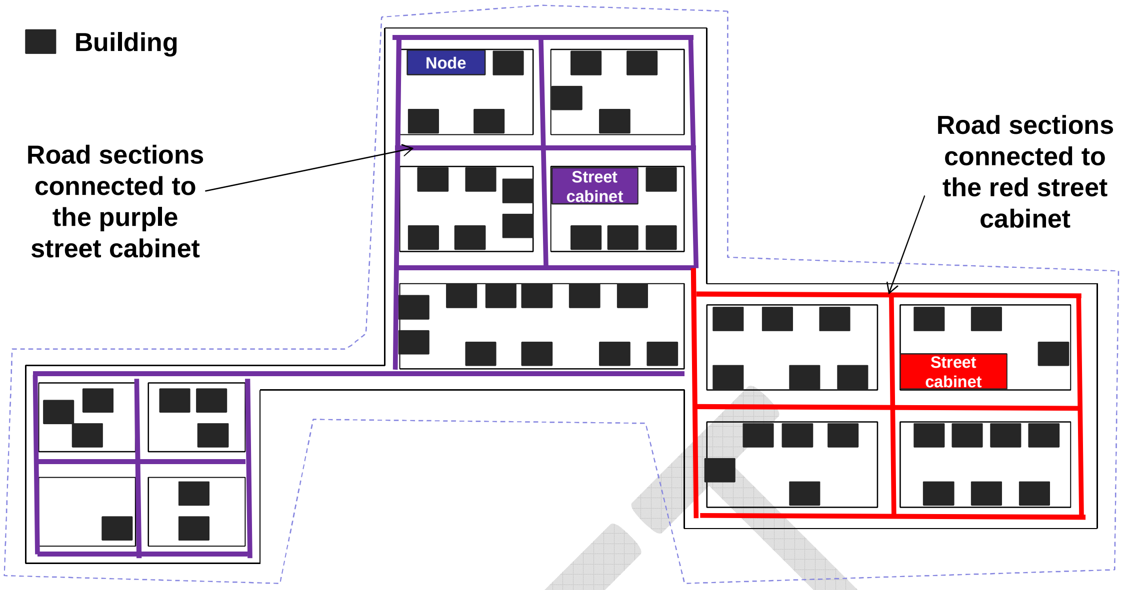
Criterion BU 48: The LRAIC model should use the "shortest path algorithm" to connect two nodes together by following the real Danish road and street network.

It is important to note that, contrary to the previous LRAIC model, the LRAIC model will not use geotypes and sampling algorithms. The LRAIC model will be based on existing roads and streets of the whole networks. Cables and trenches will be deployed in each of these roads and streets, making the need for sampling algorithms unnecessary. Geotypes can however be used by SMP operator to provide different unit costs for different areas of the country.

For illustrative purpose, the figure 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.

Figure 14: A node area and the shortest path possible between street cabinets and building groups



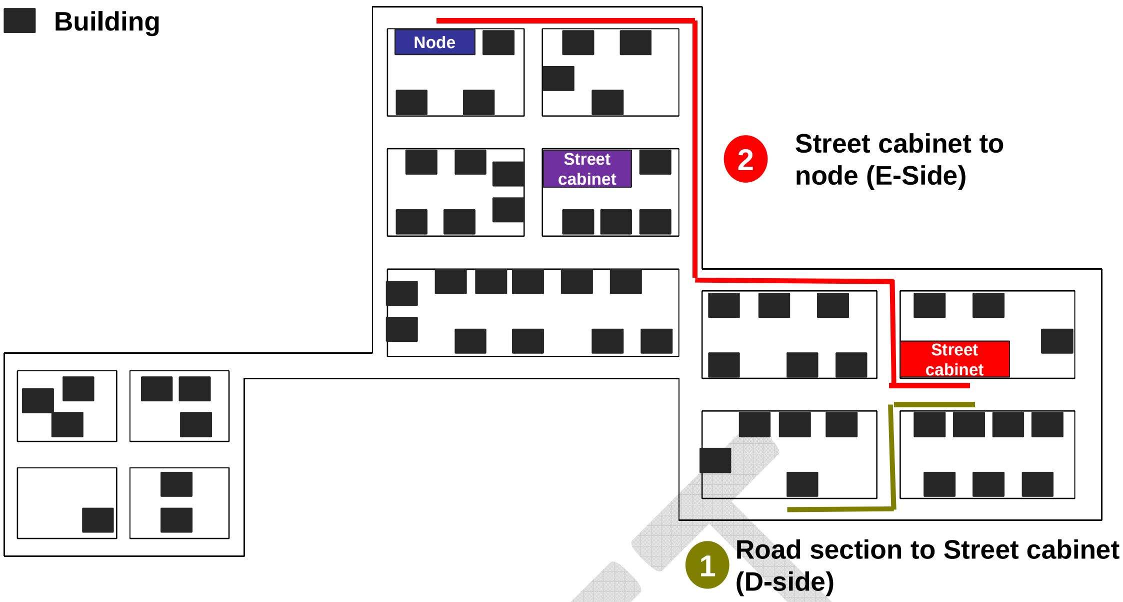
Source: TERA Consultants

For 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. Therefore the red section roads are connected to the red street cabinet and the purple section roads are connect to the purple 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.

Figure 15 : Configuration of the shortest possible path for E-side and D-side



Source: TERA Consultants

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

4.3.2.3 Network dimensioning[63]

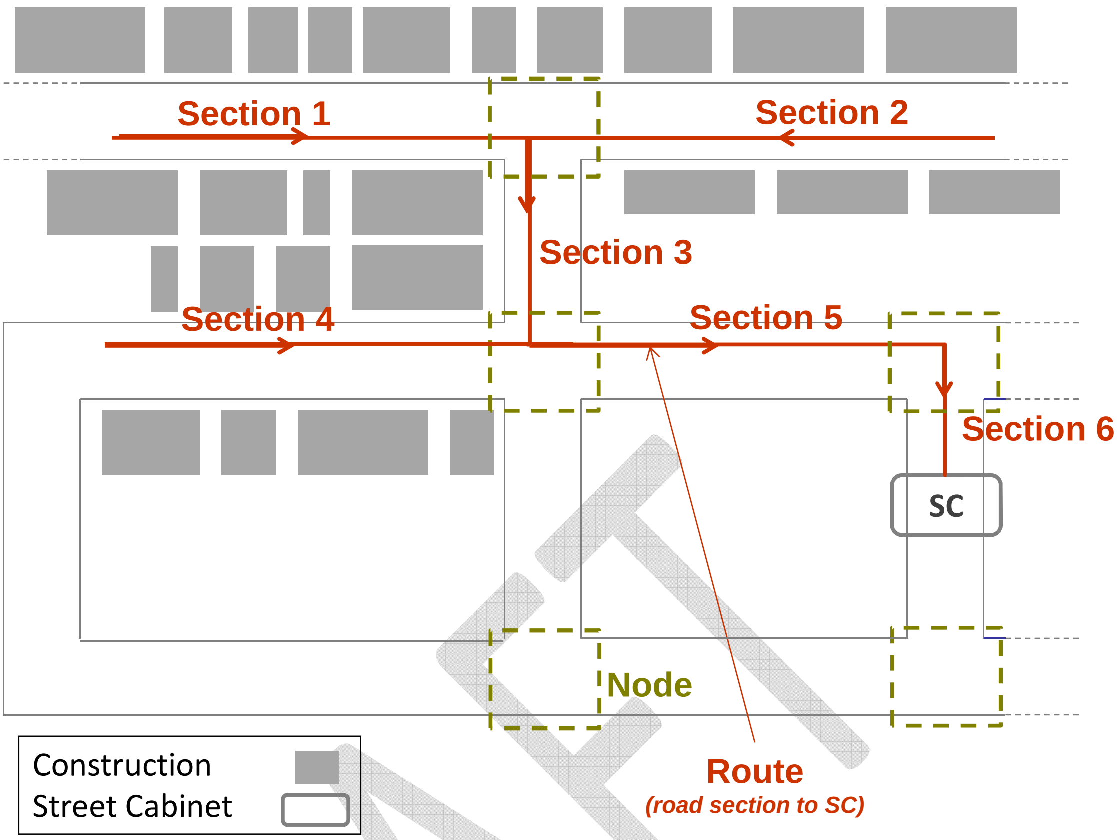
Using the road network database and the shortest path algorithm, it is possible to determine exactly on each section which network elements should be rolled out in every part of the country:

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

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

[63] New criteria compared to former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

Figure 16 : Shortest path algorithm applied to a simple road network



Source: TERA Consultants

- 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 figure, 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.

Figure 17 : route identification applied to previous road network

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		

Source: TERA Consultants

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 capacities), it is possible to assess exactly the number of copper pairs/fibres/cables needed on each section;
- Using the list of available cables[64], 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 4.4.3

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 possible 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).

Criterion BU 49: The access network should be dimensioned at the section level. The transmission part of the core network should also be dimensioned at the section level.

[64] This list includes all the types of cables (including their size: number of pairs, number of fibres) that TDC has used for its latest deployments. This list should specify the use that is made of each cable category (e.g. one type of cable is only used to connect the exchange to the PDP).

4.3.3 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.

4.3.3.1 Costing capital expenditures[65]

The key parameters of calculating capital expenditures are the following:

- Current asset cost and asset life (see §3.2) ;
- WACC (see §3.5);
- Depreciation method (see §3.4).

To calculate capital expenditures, it is also necessary to allocate costs between access and core networks since both networks share some assets (trenches). As explained in section 4.3.2.3, dimensioning ducts and trenches require identifying at the section level the presence or not of cables rolled out for the access network and for the core network. For road sections shared by both the core and the access networks, the following allocation rules can be used:

- 50/50: each network is being allocated half of the shared part;
- Number of cables: each network is being allocated costs of the shared part in proportion of the number of cables it uses;
- Cables section (surface of core cables versus access cables): each network is being allocated costs of the shared part in proportion of the total surface of cables it uses.

If there are only access cables in one section then 100% of the trench costs should be allocated to the access network and reciprocally, if in one section, there are only core cables, then 100% of the trench costs should be allocated to the core network. Same rules can be used for sharing with other types of networks (such as electricity networks).

Criterion BU 50: The cost of shared assets (trenches and possibly ducts) between the access and the core networks should be split between the two networks using one of the three rules described above, depending on network specifics.

[65] In line with former MRP: DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

4.3.3.2 Costing operating expenditures

As indicated in section 3.3, operating costs are calculated using the operators' actual costs (top-down) with adjustments or with a bottom-up calculation depending on the feasibility (e.g. information availability) of both approaches.

4.3.4 Costing Services[66]

This stage aims at determining the cost per line (copper, fibre, or cable TV) at the national level and at the MDF/ODF/MPEG level. This cost per line is a key input to determine service costs.

For that purpose, the sum of annualised capital expenditures and operating costs are divided by the appropriate number of <u>active</u> lines (for which forecasts are necessary).

The LRAIC model will have the ability to assess the costs at different geographical levels (national, MDF/ODF/MPEG) which will enable the comparison of the cost distribution over the country (see §5.1).

Criterion BU 51: The LRAIC model should compute a cost per line for each network at the national level and at the MDF/ODF/MPEG level by dividing the sum of the annualised capital expenditures and the operating costs by the appropriate number of future steady-state (forecasted) active lines.

4.4 Modelling Core

4.4.1 Demand Over the Core Network[67]

This section examines the issues involved in estimating both the user demand and the dimensioned demand.

4.4.1.1 Estimation of End-User Demand

The main source of information on the current level of demand in Denmark will be the SMP operator, today TDC. The model should include all the current traffic, including broadband, leased lines and other services, including those offered by other operators to end customers via the SMP operator's network.

An assumed rate of growth (which could be positive or negative) over the assumed planning period needs to be added to the current volume of traffic in order to get to the end-user demand. The decision of which growth rate to use is based on an assessment of the time factor involved in increasing/decreasing the capacity of relevant parts of the network.

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[66] New criteria compared to former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

[67] In line with former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

Different margins for growth will need to be specified within each set of services. For example, higher bandwidth leased lines would have a different growth rate to lower bandwidth leased lines. Widely accepted growth rates for broadband for example are the forecasts computed by Cisco.

The primary purpose of the forecasts is to ensure that the modelled networks are dimensioned appropriately. The network should be able to meet the demand not only in the base year but also in the foreseeable future. The network dimensioning should correspond to what an efficient operator facing the forecasts would do.

Criterion BU 52: The LRAIC model should show the anticipated growth per annum for each service, with the modelled networks dimensioned appropriately. The model should be flexible enough to allow for changes in margins for growth.

4.4.1.1.1 Voice Telephony traffic

The model should show both annual minutes and number of calls for all the voice telephony products (including VoIP services). The obvious source of this information is billed minutes and number of calls recorded by TDC. These, however, do not capture the total demand placed on the core network, because they do not include unsuccessful calls, ringing time or blocked calls.

Criterion BU 53: When measuring the current level of voice traffic, the LRAIC model should take account of unsuccessful calls and ringing time which are not charged and, therefore, not included in traffic statistics.

4.4.1.1.2 Broadband

As a minimum, the model should be able to identify the number of customers (split by residential and business) for each of the major broadband service tiers, and the average usage for each tier in terms of Gigabytes downloaded per month. Additional information should be sought to identify how "peaky'' the usage of broadband is such that the maximum demand placed on the core network (in terms of peak Gigabits per second and/or peak Mega-packets per second) can be estimated.

Criterion BU 54: The LRAIC model should have the capability to be able to show the demand for each major broadband service tier, both in terms of the number of customers and also in terms of the monthly download usage.

4.4.1.1.3 Leased lines

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

Proportionate 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.

It is expected that this should constitute a significant implementation issue in the LRAIC model development. As a consequence, specific attention should be paid to this issue and detailed discussions should happen with the SMP operator. It may be necessary to obtain a list of all leased lines sold by the SMP operator and to get for each leased line:

- The speed;
- The contention rate;
- The MDF end locations;

This information may then be used to derive routing factors or demand on a route by route basis (see §4.4.1.2.1).

Criterion BU 55: 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. For this purpose, a detailed list of the SMP leased lines with their features (speed, contention rate, locations of the ends of the leased line) may be needed.

4.4.1.1.4 Other Services

Different data services feature different characteristics, especially in terms of traffic take-up. However, certain data services might be implemented in terms of "platforms' ' (essentially, having a given amount of effectively leased line capacity allocated to them). When the latter is the case, it is sufficient to identify the capacity of the platform rather than the services that run over it.

Certain new services that already run over the IP network might be becoming increasingly popular. A good example of this would be multicast IPTV or Video on Demand. Where such services exist, and have a significant customer base, relevant information should be sought on the customer numbers and services provided (such as number of TV channels, and bandwidth per channel).

Specifically, modelling of the multicast IPTV service should reflect the outcome of the work currently conducted in the multicast working group.

Criterion BU 56: Demand for other services should be shown by different categories of services and, within each category, by different capacity bandwidths. Particular attention should be placed on platforms provided for other data services, and on new, high-growth services that already utilise the SMP operator's existing IP network. Modelling of multicast IPTV should reflect work conducted in the multicast working group.

4.4.1.2 Estimating Dimensioned Demand

Once the end-user demand has been estimated, the model will need to show how this has been adjusted to estimate the "dimensioned demand' ' which the network must satisfy.

The adjustments include:

- the application of routing factors;
- the adjustments for grade of service ;
- allowance for resilience;
- consideration of how fast the service will be taken up; and
- application of "busy" hour estimates.

4.4.1.2.1 The application of routing factors

End-user 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 end-user demand.

There are two principal 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.
- Routing factors. Routing factors are defined as the average frequency that a particular service uses a given network element.

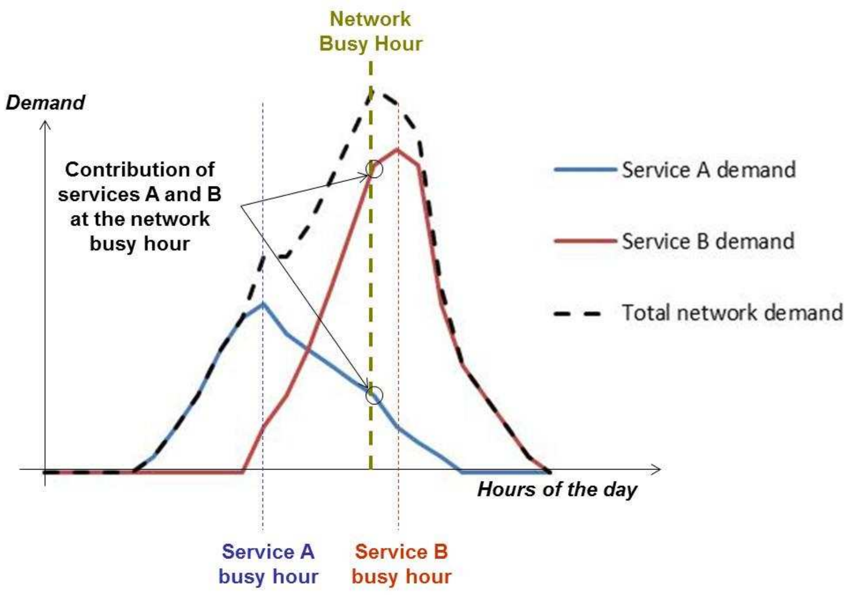
The DBA recommends that routing factors should be used as the default method to distribute the forward-looking level of demand over the different parts of the network. Route-by-route demand might be more suitable in certain cases, for example with regard to high speed leased lines.

Criterion BU 57: The routing factors used in the model need to be consistent with the underlying network architecture. The LRAIC model should separately identify, for each service, routing factors for the switching and the transport network.

4.4.1.2.2 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 or a deluge of phone calls in connection with a TV show. It should be noted that "busy-hour" can vary in different parts of the network and for different services (for example, voice calls and 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 (see Figure 18). However, for the Shapley-Shubik calculation, traffic at busy hour for each service would be needed for network dimensioning[68].

Figure 18 : Busy hours occur at different times of the day for the different services



Source: TERA Consultants

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

[68] In the Shapley-Shubik calculation scenarios where standalone services are supported by the network are considered.

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.

Criterion BU 58: 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 SMP operator for all relevant services.

4.4.1.2.3 Adjustments for the grade of service

For real-time traffic, including but not limited to voice telephony, 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 SMP operator, particularly for real time traffic (such as VoIP and IPTV) and non-contended ("leased lines') traffic.

Criterion BU 59: The LRAIC model should demonstrate that the modelled network provides services at an appropriate level of quality for an efficient SMP operator, particularly for real time traffic (such as VoIP and IPTV) and non-contended ("leased lines") traffic.

4.4.1.2.4 An allowance for resilience

In the event of switching or transmission failure, alternative routes need to be available in order to avoid loss of traffic. The network needs to allow for such redundancy.

The ability to provide services under breakdown or overload conditions is known as network resilience. Methods of improving resilience are:

- Diversifying the physical routing (trench routes) of circuits making up key traffic routes;
- Using logical rings in the configuration of the transport network;
- Controlling automatic alternative routing of traffic to avoid congested or failed nodes/links; and
- Real-time network management to monitor network performance and take action to overcome congestion.

Moreover, different services require different resilience standards. Adjustments for resilience, therefore, need to take into account how the network has been configured and that different services requiring different reliability standards imply different resilience adjustments.

Criterion BU 60: The LRAIC model should show how service-specific requirements for resilience have been taken into account both in the modelled network architecture and in the sizing of the network elements.

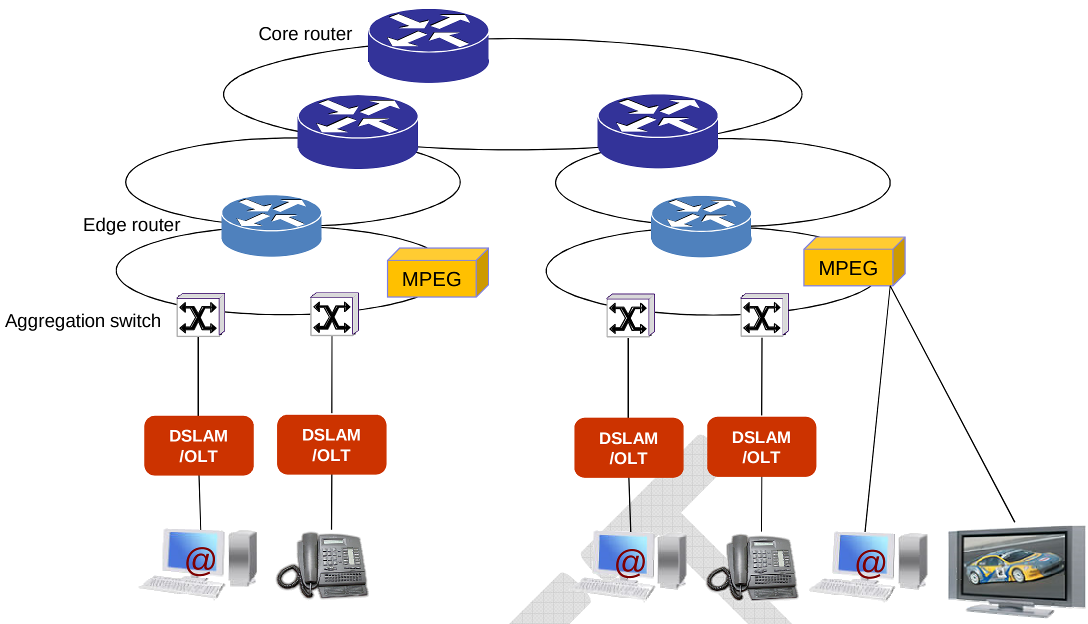
4.4.1.3 The Hierarchy of the "Exchanges"

The LRAIC model is to adopt an "all-IP" core 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 second 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 Edge Routers feeding into two (for dual parenting reasons) Core Routers.
- Edge Routers. These represent the first level of IP routing within the network and would typically be installed in rings, with a number of Aggregation switches feeding into two (for dual parenting reasons) Edge Routers on a ring.
- Aggregation switches. These are managed Ethernet switches, used to group together a number of DSLAMs/OLTs/cable TV equipment and also to form high capacity rings in dense (typically business) urban areas.
- DSLAMs or other access equipment (such as OLTs, CMTS nodes, etc.). 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)

Figure 19 – Exchanges four layer hierarchy



Source: TERA Consultants

The exchanges hierarchy has not changed in reality since the last update of the LRAIC model. Therefore the same hierarchy should be used.

The only change is that DSLAM with DSL cards should be modelled instead of POTS cards in accordance with the final MEA report.

Criterion BU 61: The hierarchy of the exchanges adopted in the LRAIC model should be kept unchanged. The only change should be the use of DSL cards instead of POTS cards.

4.4.1.4 Equipment at each node

The total number of exchange sites (nodes) in TDC's network will be the starting point for the modelling of the exchanges in the LRAIC model, based on the scorched node assumption. The precise equipment to be located at each node site should take account of the selected hierarchy and also of the end-user demand at each site.

However, the structure of the network to be modelled should be in line with the output of the Market 3 decision and the upcoming Market 2 decision with regards to the number of points of interconnections (PoI) to be considered. This should be taken into account for example when setting the number of Media Gateways.

4.4.1.4.1 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 a number of ways to determine the number of nodes in this layer of the hierarchy.

- The number of core routers in TDC's existing 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.

4.4.1.4.2 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 need 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 (sub-) loops.

4.4.1.4.3 Equipment specific to voice telephony

Although in theory, there is no specific need for specialised equipment to handle voice communications over an IP network (Skype being a good example of this), the network being modelled is one that will replace a “five nines availability” TDM-based voice telephony network and is one that will still need to interconnect with other operators that still retain TDM-based networks.

Because of this, the modelled network design will need to incorporate equipment that is specific to voice telephony services. In particular, it will need to include soft switches (to handle call set up and call administration), IMS and Media Gateways (to handle TDM-based interconnect). Session Boarder Controllers (SBC) can also be needed but Media Gateways generally have the SBC functionalities and therefore it is not necessary to model SBC separately.

The bullets above that are to be used to guide the overall hierarchical design should also be used to determine the requirements for voice telephony specific equipment (such as, for example, the number and location of soft switches and media gateways).

As explained in the final MEA report, the LRAIC model should be able to model both TDM and IP-IP interconnection.

Criterion BU 62: The hierarchical design adopted in the LRAIC model should have regard to the following factors: cost, the impact on other parts of the network, security, technical feasibility, and consistency with the evolution of the telecoms networks.

4.4.1.5 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.

Criterion BU 63: The LRAIC model will need to show the annualised direct network costs and the associated operating costs making up the relevant network elements.

4.4.1.6 Indirect network 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 determined explicitly within the model, but occasionally may need to be estimated in other ways (such as through the use of a "mark-up" on the direct network costs as an approximation) (see §3.3).

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 SMP 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 SMP 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. An advantage of this approach is that it also allows an estimate of one of the important cost elements of co-location to be determined from a bottom-up perspective (as the costs of co-location vary by location) (see §3.3).

Costs of installation, support systems, accommodation, power, and cooling should be shown separately within the model.

Criterion BU 64: The LRAIC model should estimate the costs of accommodation by looking at the square metre requirements of modelled equipment and also the costs of equipment space in different parts of the country. This will also enable accommodation costs to be allocated in a cost-causal way. Costs of installation, support systems, accommodation, power, and cooling should be shown separately within the model.

4.4.2 Modelling Transmission[69]

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

[69] In line with former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010

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.

Criterion BU 65: Repeaters should only be used on long distance routes. Any use of microwave links within the core network will also need to be justified.

4.4.3 Modelling Infrastructure[70]

Modelling infrastructure is a very important part of modelling the core network because the infrastructure is likely to be the most expensive part, accounting for up to 80 per cent of the investment in an all-IP 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 cable (and ancillary items such as manholes, fibre splicing trays etc.).

Criterion BU 66: The LRAIC model should identify infrastructure costs associated with the different assets used in different parts of the network. The model should identify separately the costs of cable, duct and trenches.

4.4.3.1 Core cables

Contrary to the access network, the core network includes often redundancies. Furthermore the path followed by the core cables may not be the shortest path between two core nodes and the redundancies 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.

In accordance with §2.3.2.3 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

[70] New criteria compared to former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

of the network), existing configurations and assessment of the impact of DWDM in the need for fibre in TDC's network.

The length of each cable on each section should be the length of the existing sections where there is core cables.

Criterion BU 67: The core cables network data should be collected from the SMP operator.

4.4.3.2 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.

Criterion BU 68: The length and the cost of the core ducts should be derived from the core cables calculations.

4.4.3.3 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).

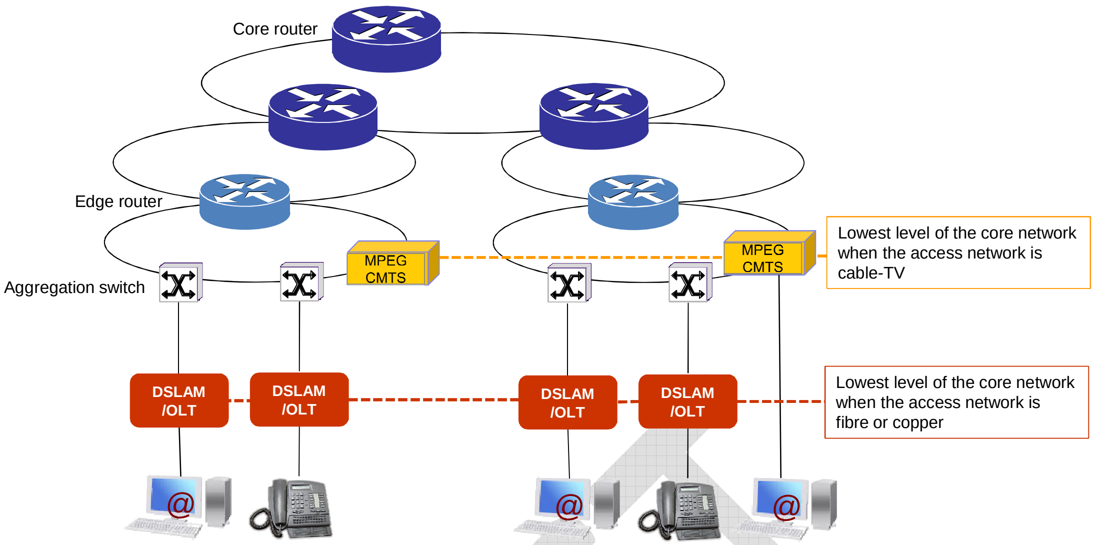
The trenches are shared between the core network and the access network as explained in section 4.3.2.3

Criterion BU 69: 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.

4.4.4 Specifics to the Cable TV Network

For the cable TV network, the MPEG stations are the lowest level of the core network. MPEG stations are collocated with CMTS that are used to provide broadband services. These are located at the aggregation level. For the FTTH and copper networks, the lowest level of the core network is located at the DSLAM/OLT level and it is understood that they generally aggregate much less lines than MPEG stations (see §4.3.2).

Figure 20 – Core lowest levels



Source: TERA Consultants

The part of the core network located between the aggregation nodes and the DSLAMs/OLTs is therefore specific to FTTH and copper technologies:

- The cable-TV access network starting point is the MPEG station located at the aggregation switch level;
- The copper and FTTH access networks starting points are respectively the DSLAM and the OLT which are at a lower level than the aggregation switches.

The core network part located between the aggregation switch level and the DSLAM/OLT level should therefore be allocated only to the fibre and to the copper networks.

In order to achieve this, it is thus important to isolate this part of the core network.

Criterion BU 70: The LRAIC model should isolate the part of the core network located between the exchange nodes (e.g. DSLAM/OLT) and the aggregation nodes in order to be able to allocate the cost related to the copper and the FTTH networks only.

4.5 Co-location [71]

4.5.1 Definition of Co-location

The LRAIC model should include the co-location services, which includes:

- Access to place on another provider's premises one's own exchange and other equipment intended to transmit and control signals between specific termination points in connection with the exchange of traffic, lease of infrastructure capacity or service provider access.
- Access to carry out one's own operation and maintenance of exchanges and equipment.

The co-location services are:

- Co-location space (indoor m² and outdoor m²);
- Rack space;
- Power supply;
- Cables.

4.5.2 Modelling Co-location services

The cost categories to be modelled include the costs of installation, accommodation, and provision of security.

4.5.2.1 Installation costs

Installation costs arise for two reasons. First because the SMP operator is entitled to ensure that its own network is not put at risk by the access seeker's equipment. This may require the construction of solid partitions or alternative measures, such as wire mesh. In the following this is referred to as "room build'. Secondly, because the SMP operator has to provide some functionalities to the access seeker's equipment to work. This includes the provision of internal and external tie cables, in-span fibre optic cable, installation of air conditioning equipment, racks, power equipment etc. Some of these costs are user specific, i.e. have no value for successive users.

Criterion BU 71: Estimates of installation costs should take into account room build and the additional equipment required. These will both depend on the type of unbundling under consideration (fully unbundling or shared access), a forecast of the number of operators seeking access to access lines and the kind of services (cooling, security etc.) that the SMP operator is requested to provide.

[71] In line with former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

Any user specific installation costs should be shown separately from room build and other general installation costs.

4.5.2.2 Accommodation costs

The model should estimate accommodation costs by explicitly looking at their cost.

The LRAIC model should use the existing location of the SMP operator's sites (scorched node assumption) and assume that only the space that is needed will be modelled for co-location. This implies that vacant space will not be included within co-location costs.

Common site costs (power, security, maintenance and other on-going expenses) should be allocated to access, core and co-location services.

Criterion BU 72: Estimates of accommodation costs should be on a per square meter basis. When appropriate, these costs should vary by location. Common site costs should be allocated to access, core and co-location services. These costs should not vary by location unless differences can be justified.

4.5.2.3 "Other Services" related to co-location

Some services do not utilise the access or core networks. This is because they are services related to very specific work processes. Costs of these services should be modelled from a pure bottom-up perspective with focus on the specific activities relevant for each service.

Most of these services mainly consist of operating costs (e.g. visits in the facilities where colocation is operated). Calculations should be based upon the activities connected to the delivery of the service, with the description of the required tasks based upon information from TDC and the DBA's interpretation of TDC's standard offers.

4.5.2.3.1 General Assumptions about Hourly Rate and Overhead Cost

When it comes to estimating work processes/tasks and derived costs of the individual service, the tasks and processes should be divided into cost driving activities in order processing and carrying out of the order. Furthermore, when modelling the cost of each service, distinction should be made between the time spent by administrative personnel, academic personnel, and technicians. To calculate the cost of delivering the service, the estimated time spent should be multiplied with the relevant hourly rate. The hourly rates for administrative personnel, academic personnel, and technicians should be shown separately within the model, even if the same hourly rate is used. Finally, the cost base can also contain other specific costs related to the order processing or actually carrying out the order where deemed necessary.

Criterion BU 73: Estimates of work processes and tasks should be based on the time spent by administrative personnel, academic personnel and technicians and on the relevant hourly rates. Each should be shown separately.

4.5.2.3.2 Prevention of Double Counting of Order Processing and Transport

In relation to each service, it should be evaluated to which extent a task is a natural extension of another service and to which extent transport, for example, is shared with other services. Moreover, it should be evaluated whether the SMP operator, with good reason, might bundle orders within the same geographical area and, thus share the time for transport between several orders.

The following principles should be applied:

- If a task in relation to service B always is carried out as an extension of a task carried out in relation to service A, and service A is a technical pre-requisite for service B, then service B should only contain the extra, incremental cost derived from the extra work process undertaken in relation to service B. This implies that no party can be made to pay for tasks not related to the ordered service.
- If a task in practice is carried out at the same time as a task related to another service, but the services are not necessarily pre-requisites for each other, an adequate allocation of time consumption should be made. The allocation should take the frequency of how often the processes are carried out simultaneously.

In the actual model, the above should be implemented as weights, with the basis behind each weight included as a comment next to the input. If part of the time for transport is covered by another service, only the un-met share should be covered. The share would then comprise the weight.

Criterion BU 74: The model should avoid double counting tasks shared between different services.

It is to be noted that this criterion also applies to double counting between staff needed for co-location services and staff needed for operation and maintenance of the core and access networks. Indeed, same staff may be used in reality and their costs should not be double counting.

5 Model outputs

5.1 Geographical De-Averaging[72]

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.

The model should compute a cost per active line per area

- per MDF area for the copper network;
- per ODF area for the fibre network;
- per MPEG station/CMTS area for the cable TV network.

Criterion BU 75: Although the model currently calculates geographically averaged results, to the extent practical, it should also show costs per coverage area for each access network. This will then facilitate analysis of geographical de-averaging in order to inform future pricing decisions.

5.2 Level of Detail[73]

Some aggregation of costs is desirable to make the models manageable, but this aggregation should be limited to ensure that the models provide a detailed breakdown of costs.

[72] New criteria compared to former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

[73] In line with former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

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.

Criterion BU 76: The LRAIC model should identify cost categories such that there is only one exogenous cost driver for each. The models 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 models 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. Such costs should be capitalised only for the period in which the activities that are necessary to get the asset ready for use are in progress and should be depreciated over the entire life of the asset. Capitalised operating costs should be shown separately from the asset costs in the bottom-up model.

Criterion BU 77: Costs related to assets can include capitalised operating costs (“own work capitalised"). In the LRAIC model, these should be separately identified.

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 only showing the cost of one minute of wholesale call termination, it could be very relevant to show also the costs components of this minute of wholesale call termination service, such as: the cost of the infrastructure, the cost of transmission, the cost of the interconnection gateways, etc.

However, in order not to increase the level of complexity of the LRAIC model, this should only be carried out to a reasonable extend for wholesale services for which particular attention is paid by stakeholders.

Criterion BU 78: The LRAIC model should have the ability to show, for some wholesale services, not only the cost of these services but also the cost of the components of these services.

5.3 Charging basis[74]

Several charging bases can be used to cost a given service. These charging bases include:

- DKK per minute;
- DKK per event;
- DKK per packet;
- DKK per kbps (capacity based charging) etc.

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.

To enable each service to be priced based on the most appropriate charging basis, the architecture of the bottom-up model will be sufficiently flexible to calculate tariffs based on different charging bases.

The default charging basis implemented in the bottom-up cost model will reflect current market practices. However, if the charging base were to change in the future, conversion factors would be used (for example, using a kbps per minute conversion factor if call termination costs were to be set on a per kbps basis).

Criterion BU 79: The charging basis should be selected in order to provide the different stakeholders with the appropriate incentives and should, as a starting point, be as consistent as possible with the cost drivers of the service.

[74] In line with former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

6 LRAIC model validation and update process

6.1 Top-down validation[75]

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 actual operator data. This is a two-stage process:

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

Where considered reasonably efficient, the model's total CAPEX and OPEX should reflect those of TDC. 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.

Criterion BU 80: Information to aid a top-down validation will be requested from operators. 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.

6.1 Update process[76]

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 the 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. The DBA intends to carry out annual updates.

Such updates can be a lengthy process and require significant time for both the DBA but mainly the SMP operator. In order to facilitate the update of the LRAIC models, it is proposed to create a template spreadsheet listing key inputs of the LRAIC models which need regular updates. This template spreadsheet should be easily linked to the LRAIC model so that including the new inputs into the LRAIC model is not a lengthy

[75] Adapted from DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

[76] New criteria compared to former MRPs: DBA (NITA at the time), Model Reference Paper - Final version, 18 September 2008 / DBA (NITA at the time), Final Model Reference Paper, 3 September 2010.

process. This will also enable the SMP 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.

Criterion BU 81: The LRAIC development process should include the building of a template spreadsheet enabling easier and more automated updates of the LRAIC model.

7 Appendix

7.1 List of criteria

The criteria for the LRAIC model set out by the DBA are listed below:

Criterion BU 1: The LRAIC model should include the ability to use historic cost information for some assets.

Criterion BU 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.

Criterion BU 3: The LRAIC model should be able to calculate the wholesale call termination cost on the basis of the pure LRIC approach.

Criterion BU 4: Access and core networks should be modelled separately.

Criterion BU 5: For the core network, the increment should include all services that use the core network. For the access network, the increment should include all services that use the access network. The LRAIC of co-location is the cost incurred in providing co-location services.

Criterion BU 6: For the cable TV network, the model should enable to clearly isolate the cost of those assets uniquely associated with individual subscribers.

Criterion BU 7: The models should include line cards in the access increment. The DSLAM located at the PCP (in the case of FTTC deployment) should be considered as part of the core network. The cost of trenches should be assessed in the access model but corresponding costs should then be allocated between the core and access networks.

Criterion BU 8: The LRAIC models should include all services on the copper, cable and FTTH networks. This includes voice, broadband, TV and leased lines services.

Criterion BU 9: The models should include all standard voice and Broadband services.

Criterion BU 10: 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.

Criterion BU 11: The models should include all the “other services”.

Criterion BU 12: The model should include all the relevant copper access services.

Criterion BU 13: 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.

Criterion BU 14: Both bitstream services cited in the DBA's decision for Market 5 will be modelled for the cable TV network. Centralised BSA will be modelled as a combination of de-centralised BSA and an IP transport product. The cost model will be capable of costing CPE and should include them if TDC installs and operates them.

Criterion BU 15: The models 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 models should also be flexible enough to allow for changes in routing factors / alternative measures.

Criterion BU 16: The models should only include IP packet switch technology.

Criterion BU 17: The models should not include SDH.

Criterion BU 18: The models should include microwave at a small extent.

Criterion BU 19: The models should not include DWDM equipment in the core network.

Criterion BU 20: The models should include both PTP and PON network architectures for FTTH netwokrs.

Criterion BU 21: 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 SMP operator's network, and be able to provide functionality comparable to that of the existing products and services.

Criterion BU 22: The LRAIC model should assume that each access network technology supports 100% of TDC's local fixed network demand in terms of active subscriptions (i.e. 100% of the "copper + cable TV + fibre" demand).

Criterion BU 23: The cost of passing all the premises within an area should be modelled. Corresponding costs should be recovered over the subset of connected locations assumed to have an active subscription.

Criterion BU 24: The starting point when building the LRAIC model for the core network is the level of demand in TDC's network for all the services using the copper, cable TV and fibre access networks.

Criterion BU 25: Both the capacity-based and the Shapley-Shubik allocation rules for joint and common network costs should be implemented in the LRAIC models.

Criterion BU 26: Corporate overheads costs should be allocated on the basis of the EPMU approach.

Criterion BU 27: Prices used in the models should reflect those that an efficient operator with the bargaining power of an SMP operator would face.

Criterion BU 28: The models should model the costs for 2014. In subsequent years, the base year of the model will be adjusted accordingly.

Criterion BU 29: The models should use a Modern Equivalent Asset concept to estimate current costs. Replacement cost in the model should correspond to the cost of buying new equipment in the base year.

Criterion BU 30: Operating costs should be calculated using one of the following approaches depending on their feasibility (e.g. information availability): Top-down assessment with potential efficiency adjustments, bottom-up assessment based on a percentage of capital cost, bottom-up assessment based on necessary employees, true bottom-up assessment.

Criterion BU 31: Tilted annuities and full economic depreciation (where volumes of outputs can change significantly) should be used in the LRAIC model.

Criterion BU 32: The LRAIC model should include the facility for separate WACCs for the core, copper, cable TV and fibre networks. A review of the cost of capital to be applied as part of the pricing decisions will be undertaken and will be issued for consultation to industry as part of this process.

Criterion BU 33: The LRAIC model should have the possibility of including a risk premium for NGA networks.

Criterion BU 34: Except for working capital generated by CAPEX which should be taken into account through depreciation formulas, the cost of working capital related to network OPEX should be excluded from the LRAIC model.

Criterion BU 35: The starting point when building the bottom-up model is the level of demand in Denmark for all the services using the access and the core network of an SMP operator along with an allowance for growth.

Criterion BU 36: 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 SMP operator's network. This implies that equipment should be placed at the existing geographical locations of the SMP operator's network nodes (the scorched node assumption).

Criterion BU 37: The LRAIC model should utilise a technically feasible network based on packet switched, IP, technology. The quality level, functionality and other characteristics of the modelled network should however correspond to the voice interconnection products that the SMP operator's network is designed for.

Criterion BU 38: The model must be able to demonstrate that the optimised network can carry the dimensioned traffic with a sufficient level of resilience.

Criterion BU 39: The LRAIC model needs to demonstrate that the optimised network provides services at a level of quality and functionality, which as a minimum meets the level that the SMP operator offers today to interconnecting operators and end-users.

Criterion BU 40: Although the model will be based on an "all-IP" network, it will still need to interconnect with TDM networks. Thus the costs of interconnecting with such networks (media gateways) should be included as well as IP-IP interconnection elements.

Criterion BU 41: The LRAIC access network cost model will be based on both Microsoft Access and Microsoft Excel but Microsoft Access should be used to a minimum extend to facilitate the review and understanding of the LRAIC model by stakeholders.

Criterion BU 42: The LRAIC model should show anticipated demand forecasts for access services.

Criterion BU 43: The LRAIC model should use as much as possible locations (X;Y geographic coordinates) and coverage areas of each network node of the operators.

Criterion BU 44: The model should use the coverage areas of: TDC for the copper network, TDC for the cable-TV network and TDC's cable TV for the FTTH network (and copper network outside cable TV areas).

Criterion BU 45: The LRAIC model should use the road network database provided by a GPS data provider.

Criterion BU 46: The LRAIC model should use the data on buildings provided by KMS or equivalent sources if not available.

Criterion BU 47: The LRAIC model should use the operators' networks hierarchies.

Criterion BU 48: The LRAIC model should use the "shortest path algorithm" to connect two nodes together by following the real Danish road and street network.

Criterion BU 49: The access network should be dimensioned at the section level. The transmission part of the core network should also be dimensioned at the section level.

Criterion BU 50: The cost of shared assets (trenches and possibly ducts) between the access and the core networks should be split between the two networks using one of the three rules described above, depending on network specifics.

Criterion BU 51: The LRAIC model should compute a cost per line for each network at the national level and at the MDF/ODF/MPEG level by dividing the sum of the annualised capital expenditures and the operating costs by the appropriate number of future steady-state (forecasted) active lines.

Criterion BU 52: The LRAIC model should show the anticipated growth per annum for each service for one, three and five years, with the modelled networks dimensioned appropriately. The model should be flexible enough to allow for changes in margins for growth.

Criterion BU 53: When measuring the current level of voice traffic, the LRAIC model should take account of unsuccessful calls and ringing time which are not charged and, therefore, not included in traffic statistics.

Criterion BU 54: The LRAIC model should have the capability to be able to show the demand for each major broadband service tier, both in terms of the number of customers and also in terms of the monthly download usage.

Criterion BU 55: 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. For this purpose, a detailed list of the SMP leased lines with their features (speed, contention rate, locations of the ends of the leased line) may be needed.

Criterion BU 56: Demand for other services should be shown by different categories of services and, within each category, by different capacity bandwidths. Particular attention should be placed on platforms provided for other data services, and on new, high-growth services that already utilise the SMP operator's existing IP network. Modelling of multicast IPTV should reflect work conducted in the multicast working group.

Criterion BU 57: The routing factors used in the model need to be consistent with the underlying network architecture. The LRAIC model should separately identify, for each service, routing factors for the switching and the transport network.

Criterion BU 58: 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 SMP operator for all relevant services.

Criterion BU 59: The LRAIC model should demonstrate that the modelled network provides services at an appropriate level of quality for an efficient SMP operator, particularly for real time traffic (such as VoIP and IPTV) and non-contended ("leased lines") traffic.

Criterion BU 60: The LRAIC model should show how service-specific requirements for resilience have been taken into account both in the modelled network architecture and in the sizing of the network elements.

Criterion BU 61: The hierarchy of the exchanges adopted in the LRAIC model should be kept unchanged. The only change should be the use of DSL cards instead of POTS cards.

Criterion BU 62: The hierarchical design adopted in the LRAIC model should have regard to the following factors: cost, the impact on other parts of the network, security, technical feasibility, and consistency with the evolution of the telecoms networks.

Criterion BU 63: The LRAIC model will need to show the annualised direct network costs and the associated operating costs making up the relevant network elements.

Criterion BU 64: The LRAIC model should estimate the costs of accommodation by looking at the square metre requirements of modelled equipment and also the costs of equipment space in different parts of the country. This will also enable accommodation costs to be allocated in a cost-causal way. Costs of installation, support systems, accommodation, power, and cooling should be shown separately within the model.

Criterion BU 65: Repeaters should only be used on long distance routes. Any use of microwave links within the core network will also need to be justified.

Criterion BU 66: The LRAIC model should identify infrastructure costs associated with the different assets used in different parts of the network. The model should identify separately the costs of cable, duct and trenches.

Criterion BU 67: The core cables network data should be collected from the SMP operator.

Criterion BU 68: The length and the cost of the core ducts should be derived from the core cables calculations.

Criterion BU 69: 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.

Criterion BU 70: The LRAIC model should isolate the part of the core network located between the exchange nodes (e.g. DSLAM/OLT) and the aggregation nodes in order to be able to allocate the cost related to the copper and the FTTH networks only.

Criterion BU 71: Estimates of installation costs should take into account room build and the additional equipment required. These will both depend on the type of unbundling under consideration (fully unbundling or shared access), a forecast of the number of operators seeking access to access lines and the kind of services (cooling, security etc.) that the SMP operator is requested to provide. Any user specific installation costs should be shown separately from room build and other general installation costs.

Criterion BU 72: Estimates of accommodation costs should be on a per square meter basis. When appropriate, these costs should vary by location. Common site costs should be allocated to access, core and co-location services. These costs should not vary by location unless differences can be justified.

Criterion BU 73: Estimates of work processes and tasks should be based on the time spent by administrative personnel, academic personnel and technicians and on the relevant hourly rates. Each should be shown separately.

Criterion BU 74: The model should avoid double counting tasks shared between different services.

Criterion BU 75: Although the model currently calculates geographically averaged results, to the extent practical, it should also show costs per coverage area for each access network. This will then facilitate analysis of geographical de-averaging in order to inform future pricing decisions.

Criterion BU 76: The LRAIC model should identify cost categories such that there is only one exogenous cost driver for each. The models 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.

Criterion BU 77: Costs related to assets can include capitalised operating costs ("own work capitalised"). In the LRAIC model, these should be separately identified.

Criterion BU 78: The LRAIC model should have the ability to show, for some wholesale services, not only the cost of these services but also the cost of the components of these services.

Criterion BU 79: The charging basis should be selected in order to provide the different stakeholders with the appropriate incentives and should, as a starting point, be as consistent as possible with the cost drivers of the service.

Criterion BU 80: Information to aid a top-down validation will be requested from operators. 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.

Criterion BU 81: The LRAIC development process should include the building of a template spreadsheet enabling easier and more automated updates of the LRAIC model.

Among the previous list of criteria, the following ones are new ones compared to previous MRP:

- Criterion BU 1;
- Criterion BU 4;
- Criterion BU 6;
- Criterion BU 7;
- Criterion BU 12;
- Criterion BU 20;

- Criterion BU 22;
- Criterion BU 25;
- Criterion BU 28;
- Criterion BU 29;
- Criterion BU 40;
- Criterion BU 41;
- Criterion BU 42;
- Criterion BU 43;
- Criterion BU 44;
- Criterion BU 45;
- Criterion BU 46;
- Criterion BU 47;
- Criterion BU 48;
- Criterion BU 49;
- Criterion BU 50;
- Criterion BU 51;
- Criterion BU 67;
- Criterion BU 68;
- Criterion BU 70;
- Criterion BU 75;
- Criterion BU 81;

7.2 List of acronyms

Model Reference Paper	MRP

Long-run average incremental cost	LRAIC
Danish Business Authority	DBA
Modern Equivalent Asset	MEA
Public Switched Telephone Network	PSTN
Fibre To The Home	FTTH
Fibre To The Cabinet	FTTC
Optical Line Terminal	OLT
Main Distribution Frame	MDF
Moving Picture Expert Group	MPEG
Time Division Multiplexing	TDM
Internet Protocol	IP
Next Generation Network	NGN
Significant Market Power	SMP
Long-run incremental costs	LRIC
Top-down	TD-LRAIC
Bottom-up	BU-LRAIC
Bottom-Up	BU
National Regulatory Authorities	NRAs
Next Generation Access	NGA
European Commission	EC
Bitstream Access	BSA
Digital Subscriber Line Access Multiplexer	DSLAM
Cable Model Termination System	CMTS
International	IN
Passive Optical Network	PON
Point to Point	PTP
Customer Premises Equipment	CPE
Synchronous Digital Hierarchy	SDH
Dense wavelength division multiplexing	DWDM
Digital Subscriber Line	xDSL
primary cross connect point	PCP
Capital expenditure	CAPEX
Operational expenditure	OPEX

Video On Demand	VoD
Equal Proportionate Mark-Up	EPMU
Danish Krone	DKK
Line Fault Index	LFI)
weighted average cost of capital	WACC
Optical Distribution Frame	ODF
Primary Access Point	PAP
Global Positioning System	GPS
Primary Distribution Point	PDP
Secondary Distribution Point	SDP
Final Distribution Point	FDP
Distribution Node	DN
Island Node	IN
Last Amplifier	LA
Distribution Point	DP
Voice over IP	VoIP
Multi-Service Access Nodes	MSAN
Plain Old Telephone Service	POTS
IP Multimedia Subsystem	IMS
Session Boarder Controllers	SBC
Plesiochronous Digital Heriarchy	PDH
Kilobit per second	Kbps